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This is the fourth compilation of annual reports for the Navy's ELF Communications System Ecological Monitoring Program. The reports document the progress of ten studies performed during 1985 at the Wisconsin and Michigan Transmitting Facilities. The purpose of the monitoring is to determine whether electromagnetic fields produced by the ELF Communications System will affect resident biota or their ecological relationships.

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19. Abstract (Continued)

H.  Aquatic Ecosystems
    Michigan State University
    Burton, T.M.; Stout, R.J.; Taylor, W.W.; Muzzall, P.M.; Oemke, M.P.;
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I.  Wetland Studies
    University of Wisconsin-Milwaukee
    Stearns, F.; Guntenspergen, G.; Keough, J.; Wikum, D.

J.  Bird Species and Communities
    University of Minnesota-Duluth
    Niemi, G.J.; Hanowski, J.M.

## FOREWORD

This document is the fourth compilation of Annual Reports on the Extremely Low Frequency (ELF) Communications System Ecological Monitoring Program initially authorized under Naval Electronic Systems Command Contract N00039-81-C-0357 to IIT Research Institute (IITRI). The studies in this Program are now being continued under Space and Naval Warfare Systems Command Contract N00039-84-C-0070. IITRI provides engineering support and coordinates the efforts of investigators in 10 studies, all of which are being conducted under subcontract arrangements between IITRI and the study teams.

The purpose of the Ecological Monitoring Program is to determine whether electromagnetic fields produced by the Navy's ELF Communications System will affect resident biota or their ecological relationships. Biological aspects of 16 general types of organisms and ecological aspects of three ecosystems are being monitored in Wisconsin and Michigan.

The originally proposed study objectives, monitoring protocols, and analytical techniques were presented in the 1982 compilation of annual reports. Changes and study progress are documented in subsequent compilations. Commencing in 1983, each annual report has been reviewed by four scientific peers. Two of the four are selected by the reporting investigator; the other two are selected by IITRI. Critiques are supplied to the authors for their consideration in finalizing their annual reports and in planning the next field season.

Each compilation was printed from original copies of each investigator's report for 1985 without change or editing by either IITRI or the Space and Naval Warfare Systems Command.

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**INDEX OF 1985 ANNUAL REPORTS**

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I.  Wetland Studies
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    University of Minnesota-Duluth
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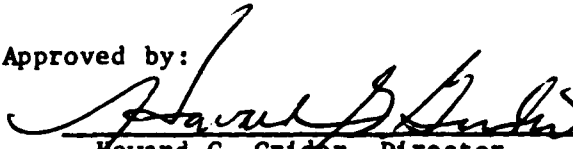AQUATIC ECO- SYSTEMS-TASKS 5.8, 5.9, 5.10




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## III.  TABLE OF CONTENTS

## IV. SUMMARY

The following is a summary of the data base collected from 1 November 1983 to 31 October 1984 summarized by the elements listed in the 1983-84 work plan. Some previous 1982 and 1983 data are included where needed to complete overall trend analysis.

### Element 1 -- Conduct Ambient Monitoring Program

All automatically monitored data from 1983 and 1984 have been summarized and daily averages for most of the growing season are available for both years. These data have subsequently been used in correlations with biotic data.

In summary, ambient monitoring data are available to fulfill the objectives for this element. These data show that FCD and FEX are very comparable sites with only minor differences from site to site. These data also demonstrate the excellent water quality of the Ford River. These data have been used in the biotic monitoring program with correlations between periphyton, insects, and fish and appropriate ambient monitoring data have been examined. The correlations between various physical and chemical parameters reported in this element will be useful in interpreting the results of correlations between ambient monitoring and biotic parameters.

### Element 2 -- Monitoring of Species Composition, Numbers, Diversity, Biomass Production, Cell Volume and Chlorophyll a/Phaeophytin a Production for Periphyton

#### 1. Chlorophyll a

Annual patterns for chlorophyll a standing crop and accrual were characterized by considerable year-to-year variability. The only consistency between data for 1985 and data for the two previous summers was a July-August peak. 1 This peak varied in magnitude between years but always occurred. 1 In 1985, no site differences were detected (p < 0.05) between FCD and FEX for chlorophyll a. Differences had occurred in 1983 and 1984. This lack of intersite difference in 1985 coupled with use of 3-way ANOVA analyses suggest that this parameter can be used to detect differences which may occur between sites once ELF exposure begins.

#### 2. Organic Matter

Organic matter standing crop and accrual rates showed considerable year to year variability as had chlorophyll a. These parameters have consistently been characterized by no significant differences between sites since the start of the project in 1983. This trend continued in 1985. The only

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year to year consistency has been a July-August peak in standing crop and accrual rates.

### 3. Chlorophyll a to Phaeophytin a Ratios

This ratio continued to vary widely throughout the year in 1985. It is not a useful parameter for detection of ELF effects.

### 4. Diatom Cell Density

Diatom cell density continued to be characterized by no statistical differences between sites ($p < 0.05$). Trends in cell density do not include a July-August peak. Instead, individual numbers tend to be high throughout the summer with some tendency towards a June peak. Conversely, individual cell volume tends to be higher in the winter.

### 5. Species Diversity and Evenness

Diatom species diversity and evenness was not significantly different between FEX and FCD in 1985 continuing the trends established in 1983 and 1984. Annual trends continued to be characterized by high diversity and evenness during winter with lower values during the summer.

### 6. Total Biovolume and Individual Cell Volume Studies

Individual cell volume of the 20 dominant diatom species were not significantly different between the experimental and control sites. 1 total biovolume was significantly larger at the control site than at the experimental site.

### 7. Correlation with Environmental Variables

Multiple regression analyses and correlation matrices suggested that chlorophyll a standing crop was correlated with (1) above water solar radiation, discharge, and water temperature and (2) total P, organic N, and dissolved silica. However, neither diatom cell density nor organic matter standing crop were correlated with these parameters. No single parameter or set of environmental parameters were capable of predicting all three of the major biological parameters (cell density, chlorophyll a and organic matter standing crops or accrual).

### 8. Photosynthesis-Respiration Studies

Net production, respiration, and grow production of the community on rock surfaces did not differ significantly between FEX and FCD in either 1984 or 1985. These measurements appear to offer a precise means of detecting ELF effects on community metabolism. Comparison of chlorophyll a data from rock surfaces compared to glass slide data

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suggested that the rock surface data offered a more precise means of intersite comparison.

Element 3 -- Effects of Exposure Period on Insect
             Colonization of Artificial Substrates

This element was deleted.

Element 4 -- Species Richness and Biomass of Stream
             Insects from Artificial Substrates in Riffles

Species diversity (H') and evenness (J') from 1983 to 1984 were highly correlated with one another. Both parameters had their highest values in the summer months and their lowest values during the winter months. High chironomid abundances greatly affected H' and J', and are highly correlated with those two parameters. If chironomids were excluded from benthic insect analyses, very different values for H' and J' would emerge.

Biomass values, when coupled with numerical abundances of certain taxa, were low in variation over time. The following taxa showed consistent size class patterns (DW/IND) from 1983 to 1985 at both sites: Chironomidae, Paraleptophelebia mollis, Ephemerella invaria, E. subvaria, and Optioservus sp. They will continue to be monitored.

Element 5 -- Movement Patterns of Selected Aquatic
             Invertebrates

Naiads of O. colubrinus travelled in a downstream direction for brief distances at both sites. In 1984, only FEX was studied. Those results are in agreement with results obtained at the site as well as at FCD in 1985. Percent recapture success is high (30 to 50%) making us rather confident that the data reflect the actual movement patterns of this predator. These animals are very appropriate animals for monitoring movement patterns because they are abundant, easily marked, and sessile. Thus, ELF effects on movement patterns of this, possibly sit-and-wait, dragonfly predator will be monitored annually.

Element 6 -- Leaf Litter Processing

Leaf processing rates (-k) were not significantly different for 1982-1983 and 1984. H' and J' values were also similar. Numbers of species (S), however, remained higher over time in 1984 as compared with 1982-1983 data. Percent dominance of chironomids on leaves was similar for 1982 and 1984. One shredder, B. flavifrons, showed similar numerical and size-class patterns in 1982-83 and 1984. A collector, E. invaria was added to the analysis in 1984. It had similar and consistent size classes for both fresh and autumn leaves at FEX and FCD. C.V. values were, for the most part, below 18%.

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### Element 7 — Feeding Activity of Grazer Populations

Techniques have been developed to allow quantification of grazer effects on periphyton community dynamics in the Ford River. These techniques consist of use of streamside plexiglass channels to manipulate grazer densities on pre-colonized ceramic tiles. In the first three experiments conducted in 1985, grazers altered levels of organic matter measured as ash free dry weight, altered species composition with decreased levels of Cocconeis and increased levels of Achnanthes but had no effect on chlorophyll a levels.

### Element 8 — Fish Community and Abundance

#### 1. Species Composition

Thirteen species from five orders and ten families were collected at FEX in 1985. This represents a net decrease in species and no change in the number of orders or families from previous years. Seventeen species from six orders and eleven families were collected at FCD in 1985 with no changes in the number of species or orders although one additional family was represented. Overall, the species composition was similar at the two sites with the only changes seen in the rare species.

#### 2. Species Abundance

The fish community was dominated by six species with creek chubs and common shiners making up to 40-60% of the catch at both sites. The burbot and white suckers showed the greatest fluctuations from year to year. Overall, the fish communities were similar from site to site, and stable from year to year.

#### 3. Catch Statistics

The catch rates of white suckers, longnose dace, burbot and common shiner demonstrated declining catch sites at both sites from 1983 to 1985. Brook trout and creek chubs showed no pattern in catch rates at either site. Catch rates for burbot were greater at FEX than FCD, and common shiners and creek chubs were greater at FCD than FEX. This can be attributed to differences in habitat between the two sites.

The mean length of the dominant species showed trends for four of the six species with no trends seen for common shiners of white suckers. Brook trout and burbot mean length increased from 1983 to 1985, and longnose dace and creek chubs displayed decreases in length. Burbot, common shiners, creek chubs and longnose dace were all larger at FCD than at FEX. Brook trout and white suckers which are highly mobile showed no differences between the sites.

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## 4. Fish Community Mobility

The Ford River fish community demonstrated a consistent mobile component as shown by all six non-salmonid species examined displaying a strong site to site movement. This movement was represented by the approximately 20% recapture rate at sites other than the marking site. Creek chubs, common shiners and burbot showed consistent year to year trends. White suckers, longnose dace and northern pike did not display a similar year to year pattern which was attributed to low sample size in 1985 for those species.

## Element 9 -- Brook Trout Movement

Brook trout catches peaked in spring-early summer at all sites except FCU. The peak occurred in June in 1984 and in July in 1985 with the movement in an upstream direction. Brook trout movement appeared to be caused by mean water temperatures exceeding the optimal growth temperature (16°C).

Brook trout (>190 mm) move from FEX and FCD upstream to the TM site based on a total of 438 tagged fish. TM was chosen over FCU on the basis of mean temperature being closer to optimal growth temperature. Recapture rates were consistent from 1984 to 1985. Movement rates were found to range between 1.1 to 5.0 km/day. Ranges from FEX to TM were similar between 1984 and 1985. Brook trout movement rates were greater in 1985 than 1984 from FCD to TM. Angler tag return data verified the above movement rates indicating that these fish move at a consistent measurable rate upstream.

## Element 10 -- Parasite Loads of Selected Fish Species

The parasite faunas of mottled sculpins between sites were comparable taxonomically and in species numbers. This was also true for the parasite faunas of longnose dace between sites. The parasite faunas of each fish species at each site were composed primarily of larval parasites that mature in fish eating birds and fish. Only R. cotti and Crepidostomum sp., and R. canadensis mature in sculpin and dace, respectively. Quantitatively, P. m. minimum metacercariae and Tetracotyle metacercariae were the most common endohelminths of dace and sculpins, respectively. Epistylis sp. was the most common external parasite of dace and sculpins at each stie. Significant differences in the prevalence and mean number of the parasite species were not found between sexes of either host species. Seasonal trends in infection rates of the parasites were not observed or were not repeated from one year to the next. In dace, the number of P. m. minimum, Neascus sp., and R. canadensis at all sites, and the number of R. cotti in sculpins at FEX and FCD significantly increased as host length increased. The number of Diplostomum sp. decreased at all sites and the number of

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*Tetracotyle* sp. and *R. cotti* in sculpins increased in length.
*Tetracotyle* sp. and *R. cotti* in sculpins and *P. m. minimum*,
*Neascus* sp., and *R. canadensis* in dace decreased in numbers
from the upriver to the downriver sites.

# V. PROJECT RATIONALE AND APPROACH

In our original research plan, we proposed an integrated study of stream ecosystems involving three aquatic components for monitoring the potential effects of ELF. These components were: 1) periphytic algae; 2) aquatic insects; and 3) fish. The design incorporated studies of ecosystem properties with studies of behavior and biology of individual species so that any effects of ELF would be quantified at the population, community and ecosystem levels.

We selected stream ecosystems as representative aquatic ecosystems rather than lakes or marshes because: (1) upstream-downstream paired plots on the same system would provide less variability than between lake comparisons; (2) migratory behavior was more likely to be important in stream organisms; and (3) our local expertise and interests were oriented more toward stream ecology.

We planned to test the effects of ELF on stream ecosystems by using paired "plots" design of selected sections of a chosen stream. Specific control and experimental sites were to be selected after the final ELF cable corridors were established. We planned to select a stream section containing pools and riffles in an area of forest just upstream of the cable corridor with maximum exposure to extremely low frequency electromagnetic radiation (ELF). This section was to be compared to a physically similar site (with regard to depth, width, flow rates, canopy cover, etc.) on the same stream far enough from the ELF cable to receive at least an order of magnitude less exposure to ELF. The two stream sections constituted our paired "plot" design. Thus, we planned to have two plots of intensive stream studies: a control site and an experimental site at the cable corridor. We expected these studies to continue for at least 3 years of preconstruction background data collection followed by at least 3 years of post construction data collection.

For each site, we planned to continuously monitor stream velocity and water depth so the discharge could be calculated. Water and air temperatures, dissolved oxygen, pH, and solar radiation at the water surface and at the stream bottom were also to be continuously monitored. We planned to sample all other chemical parameters required in the RFP as detailed in the work plan submitted in 1983/84.

In conclusion, our research plan is directed at determining the effects of low-level, long term electromagnetic fields and gradients produced by the ELF Communications Systems on aquatic plant and animal life. The integrated approach we have taken is to combine the major interrelated and interactive components of aquatic systems

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(i.e., periphytic algae, aquatic insects, and fish) and to monitor sensitive life history events and community processes critical to the basic structure and function of stream ecosystems. These include: periphyton and stream invertebrate colonization, migration, diversity, trophic level changes in density and biomass, as well as primary productivity; organic matter processing by macroinvertebrates; dynamics of fish population growth, reproduction, and survival; fish behavior including movement patterns of homing and migration, and fish pathogen and parasite loads. Since many of these processes and events are mutually dependent on one another and the interactions are complex, we feel that a holistic approach with a multi-disciplinary effort is imperative.

The data generated from this research should: (1) determine whether the ELF Communications System affects aquatic plant and animal life in stream systems; and (2) contribute to a better understanding of stream organism processes which will help clarify a number of important aspects of current conceptual models of stream ecosystem structure and function.

## VI. OVERALL OBJECTIVES AND SPECIFIC TASK OBJECTIVES

### OVERALL OBJECTIVE

Our major objective in this study is to determine the effects of low level, long term electromagnetic fields and gradients produced by the ELF Communication System on aquatic plant and animal life in streams. The study will incorporate studies of ecosystem properties with studies of behavior and biology of individual species so that any effects of ELF will be quantified at the population, community and ecosystem level.

### SPECIFIC TASK OBJECTIVES

A. Periphytic Algal Studies

The objectives of the periphytic algal studies are:
  (1) to quantify any changes in species diversity, algal density, and chlorophyll a that occur as a result of ELF electromagnetic fields;
  (2) to quantify any changes in primary productivity that might occur as a result of ELF; and
  (3) to monitor algal cell volume and chlorophyll a to phaeophytin a ratio, thereby providing an index to physiological stress of periphytic algal cells that might occur as a result of ELF electromagnetic fields.

B. Aquatic Insect Studies

The objectives of the studies of aquatic insects are:
  (1) to quantify any changes in organic matter processing rates that occur as a result of ELF;
  (2) to quantify changes in species richness, individual abundances, and species diversity of the aquatic insect communities associated with leaf packs and inorganic stream bottom substrates;
  (3) to quantify changes in upstream-downstream movements of selected aquatic insects that might occur as a result of ELF; and
  (4) to quantify trophic, behavioral, and community level changes in selected species of aquatic insects from an array of functional feeding groups (grazers, collectors, etc.).

C. Fish Studies

The objectives of the studies of fish are:
  (1) To quantify any changes in the seasonal movement patterns and abundance of the mobile fish community that occur as a result of ELF;
  (2) To quantify any changes in the rate of brook trout movement through the ELF corridor that occur as a result of ELF electromagnetic fields;
  (3) To quantify any changes in the rates of parasitism of one mobile species (longnose dace) and one sessile species (mottled sculpin) of fish that occur as a result of ELF.

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# VII. PROGRESS BY WORK ELEMENT

Element 1 - <u>Conduct Ambient Monitoring Program</u>

Changes from workplan - None.

## Objectives

The objectives of this work element are:
  (1) to provide the background data on physical and chemical parameters needed to correlate observations on biological community dynamics with environmental parameters; and
  (2) to monitor stream chemistry and physical factors to determine whether or not observed changes in community structure are related to water quality changes rather than potential ELF radiation induced changes.

## Rationale

The chemical and physical factors selected for study are known or suspected to be important controlling factors for periphyton growth, community structure, and community dynamics. Correlating these variables with the periphyton data may ultimately be useful in predicting the effects of these environmental variables on the periphyton community and thus, in separating these effects from ELF induced effects.

## Material and Methods

Ambient monitoring stations were installed at the experimental site (FEX) and at the control site (FCD) on April 29 and 30, 1985 and were operated until October 24, 1985. The data collected for 1985 continued the data collection started in July, 1983 (July through October, 1983) and continued from April 10-12, 1984 through October 22, 1984.

The stations automatically logged on Omnidata data pods (models DP211 and DP213) the following parameters:
  (1) solar radiation above (a) the surface of the stream and (b) solar radiation below the water surface about 15 cm above the stream bottom in riffle to pool transition areas using Li-Cor model LI-192SB underwater quantum sensors;
  (2) dissolved oxygen using Leeds and Northrup model 7932 portable dissolved oxygen meters with general purpose submersible probes;
  (3) pH using the Altex (Beckman) Monitor II System with specially built long term gel-filled submersible pH probes from Fisher Scientific;
  (4) water depth using Leopold and Stevens model F strip chart recorders modified for digital

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output; and
(5) air and water temperature using thermistors.

This system was designed by Eco-Tech, Inc. of East Lansing, Michigan. The pH probes were calibrated twice per week with pH 7 and 10 buffers and were routinely checked against a separate laboratory pH meter to insure accuracy. The dissolved oxygen meters and probes were calibrated twice per week with the azide modification of the Winkler procedure (APHA 1980). Air and water temperature and stream depth were also manually determined twice per week and recorded. After data were recorded for 2-3 weeks on the Omnidata data pods the data were read onto diskettes using the Omnidata Model 217 reader and an Apple II plus computer. Much of these data are archived and will not be summarized in detail here but are available for use as needed.

In addition to the manual determinations of pH, dissolved oxygen, water depth, and air and water temperature twice per week as described above, samples were taken twice per week for turbidity and suspended and dissolved solids analyses. Once per week, alkalinity, hardness, and conductivity were determined. Nutrient samples (total and molybdate reactive P, $NO_3$-N, $NO_2$-N, $NH_4$-N, total Kjeldahl-N) were taken twice per week during the field season and frozen immediately for later analysis. Samples were also taken on the same schedule for chloride (samples frozen) and dissolved silicate (samples refrigerated). During winter months (November to April), all sampling was reduced to once every four weeks, and ambient monitoring stations were removed from the field and stored.

All chemical analyses followed procedures outlined in Standard Methods (APHA 1980) or approved techniques of the U.S. Environmental Protection Agency (U.S. EPA 1979b). The quality control program recommended by the U.S. Environmental Protection Agency (U.S. EPA 1979a) was initiated at the start of the field season in 1983. Laboratory nutrient analyses (N, P, Si, etc.) were conducted using auto-analyzer techniques as outlined in the U.S. EPA manual (1979b).

Stream discharge was determined from stage (water level) - discharge relationships determined for each station using Gurley pygmy or Price-type current meters using the velocity area technique (Gregory and Walling 1973, p. 129) with at least 20 verticals per cross-section. Discharge values were highly predictable from stage height measurement using calculated regression equations with coefficients of determination ($R^2$) values greater than 0.98 for FEX and 0.99 for FCD.

Stream velocity was also recorded for the periphyton samplers (see Element 2) using the Gurley pygmy current meter about once each week.

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TABLE 1.1. Dissolved Oxygen (mg/1) and pH for the Ford River. Values are Monthly Means $\pm$ SE, N in Parentheses.

| | Control site (FCD) | | Experimental Site (FEX) | |
|---|---|---|---|---|
| | Dissolved Oxygen | pH | Dissolved Oxygen | pH |
| OCT 1984 | 10.3 ± 0.2 (14) | 7.7 ± 0.1 (4) | 10.3 ± 0.1 (14) | 7.7 ± 0.1 (4) |
| NOV 1984 | 12.9 ± 0.1 (2) | 7.8 ± (1) | 12.9 ± 0.1 (2) | 7.8 ± (1) |
| DEC 1984 | 12.4 ± 0.1 (2) | 7.5 ± (1) | 12.5 ± 0.1 (2) | 7.4 ± (1) |
| JAN 1985 | 11.7 ± 0 (2) | 7.4 ± (1) | 12.3 ± 0.1 (2) | 7.4 ± (1) |
| FEB 1985 | 10.7 ± 0 (2) | 7.5 ± (1) | 11.9 ± 0.1 (2) | 7.4 ± (1) |
| MAR 1985 | 11.6 ± 0.1 (2) | 7.7 ± (1) | 12.1 ± 0.3 (2) | 7.2 ± (1) |
| APR 1985 | 11.1 ± 0.4 (12) | 7.4 ± 0.1 (5) | 11.3 ± 0.4 (10) | 7.5 ± 0.1 (5) |
| MAY 1985 | 9.9 ± 0.1 (18) | 7.8 ± 0 (3) | 10.3 ± 0.2 (16) | 7.9 ± 0.1 (4) |
| JUN 1985 | 9.7 ± 0.1 (16) | 7.8 ± 0.2 (4) | 9.8 ± 0.2 (16) | 7.8 ± 0.2 (4) |
| JUL 1985 | 8.7 ± 0.1 (18) | 8.0 ± 0 (5) | 8.8 ± 0.1 (18) | 8.0 ± 0.1 (5) |
| AUG 1985 | 8.9 ± 0.1 (18) | 8.0 ± 0.1 (4) | 9.0 ± 0.1 (18) | 8.0 ± 0.1 (4) |
| SEP 1985 | 9.4 ± 0.2 (18) | 7.9 ± 0.1 (5) | 9.4 ± 0.2 (18) | 7.9 ± 0.1 (5) |

13
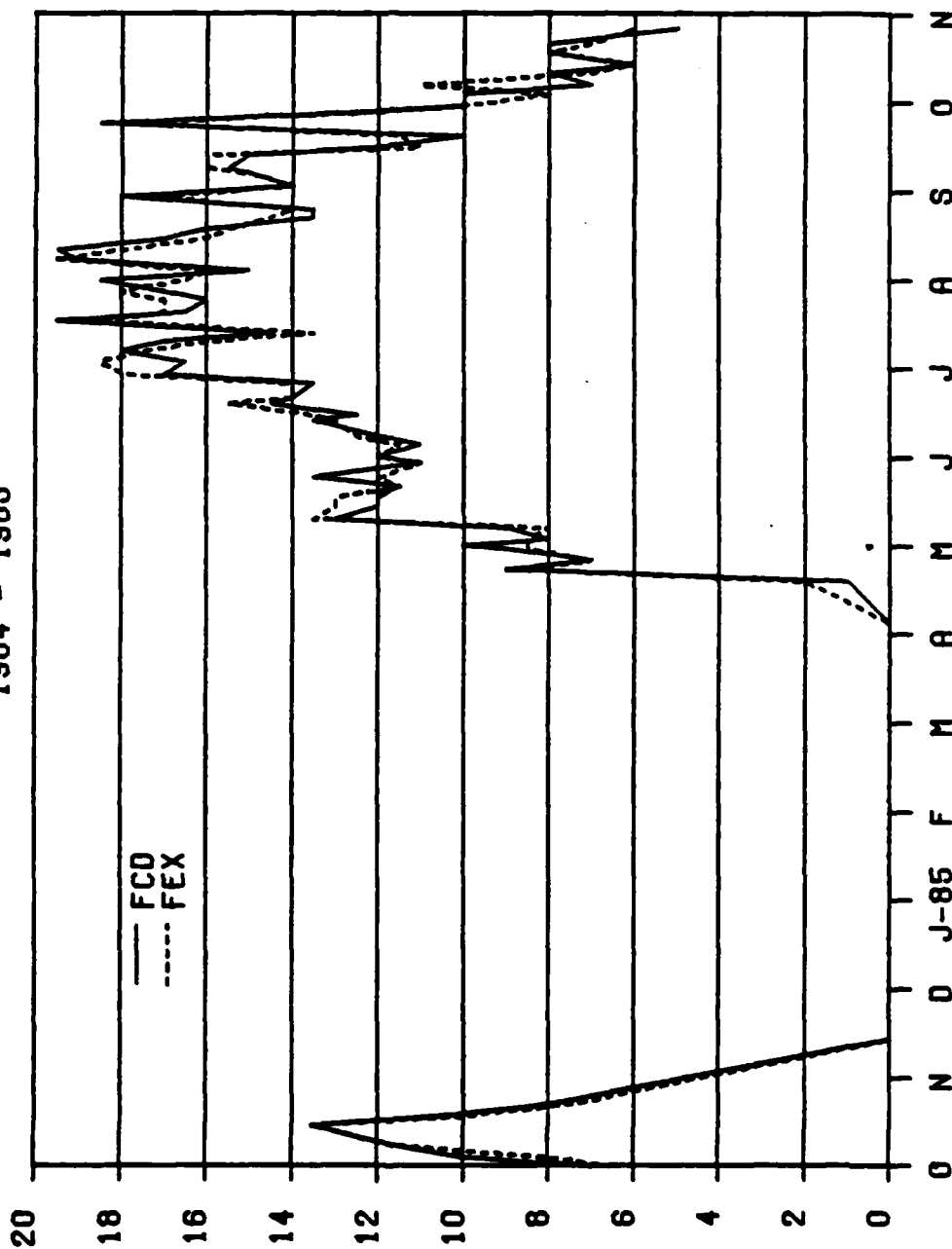
Figure 1.1. Water Temperature (degrees Celsius) for the Ford River for 1984-85.
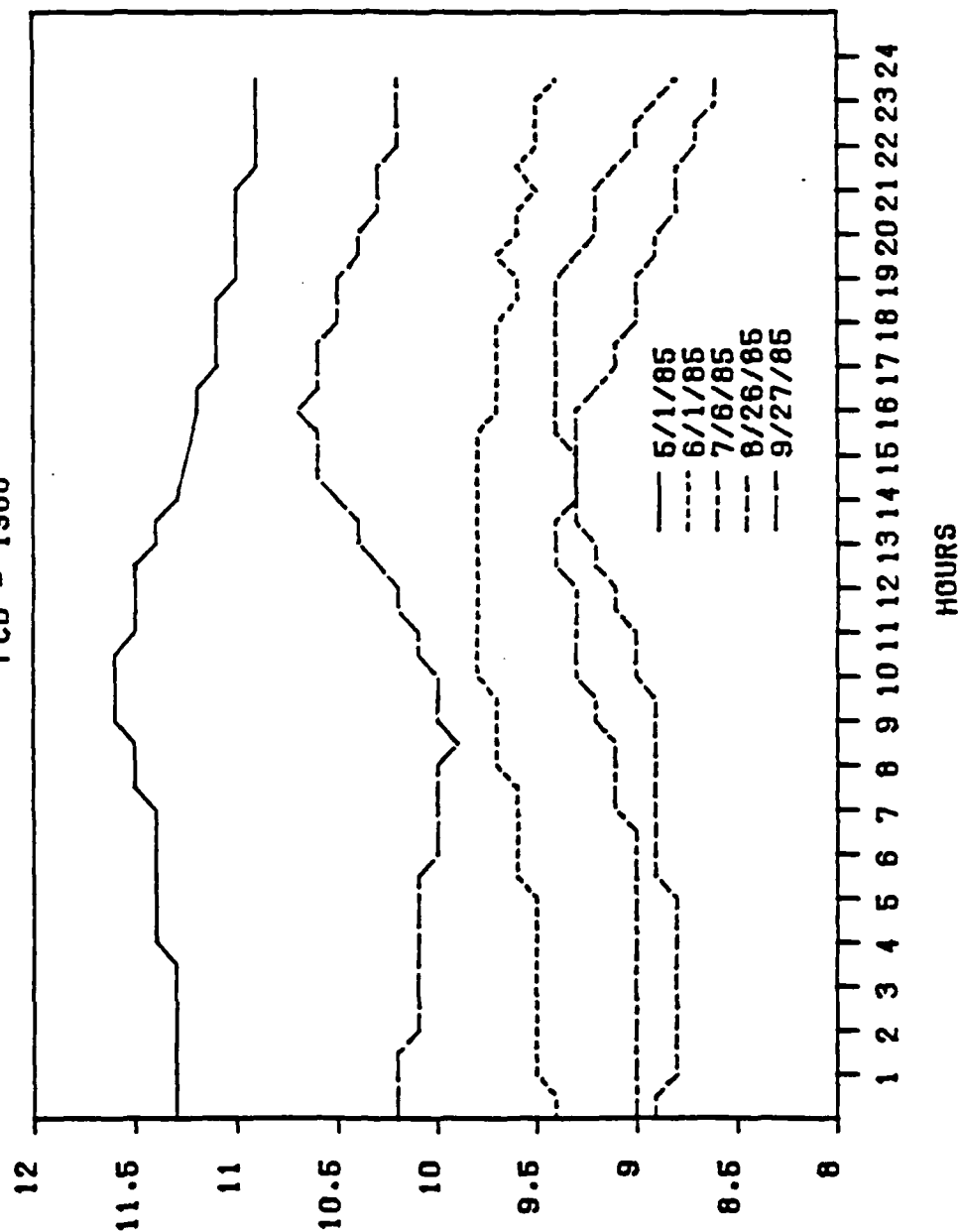
Figure 1.2. Dissolved Oxygen Meter Readings Recorded Every .5h for Five 24h Periods for the Ford River in 1985.

## Results and Discussion

The 1985 dissolved oxygen (DO) data followed the trends reported for 1983 and 1984 in the last annual report (Table 1.1). As in 1983 and 84, there was little difference between sites (Table 1.1). Also, DO values were always 1-2 mg/L below saturation after correcting for temperature (Figure 1.1), barometric pressure, and conductivity. DO did vary in a predictable manner over 24 hour cycles (Figure 1.2). However, the 0.2 to 0.5 mg/1 daytime increase over nighttime lows was well within variation predicted from temperature changes alone. There was a strong negative correlation between temperature and DO as expected (Table 1.2). Thus, autotrophic production appears to cause little increase in oxygen concentration during the day. This lack of pronounced diel changes coupled with apparent consistent undersaturation suggests that heterotrophic processes dominate in the Ford River. The river's brown water and substantial shading from the riparian vegetation for this 10-12 m wide stream are possibly responsible for the observed annual pattern of pH (Table 1.1). Highest pH values in the summer (7.9 to 8.1) were possibly correlated with carbon fixation by the periphyton and macrophytes in the river while lower winter values (7.4) could be the result of reduced photosynthetic activity. This annual pattern could also be a function of the generally lower flows in the summer (Figure 1.3) and greater soil contact time for water before it entered the river from soil and groundwater seepage. In fact, the highly predictable year-to-year variation (see 1983 and 1984 data, last annual report) coupled with a relatively strong negative correlation between pH and discharge (Table 1.2) argues for the latter interpretation. This interpretation is further supported by the fairly strong correlations between alkalinity and pH, temperature and pH, hardness and pH, conductivity and pH and negative correlations between dissolved oxygen and pH (Table 1.2).

Alkalinity and hardness in 1985 were almost identical at both the control (FCD) and experimental (FEX) sites (Table 1.3). As in 1983 and 1984 (see last annual report), low values occurred during times of maximum discharge. Also, the correlation matrix (Table 1.2) suggested that both parameters were strongly negatively correlated to discharge. Thus, regressions between discharge and these two parameters were developed for the Ford River (Figure 1.4) using log-transformed data. While there clearly is a relationship, the $R^2$ values were too low to allow precise prediction of these two parameters from discharge data alone. However, alkalinity was highly correlated with hardness (r=0.99, see Table 1.2). This relationship was expected since alkalinity is a measure of the major anions and hardness is a measure of the major cations in water. Thus, it would be possible to discontinue one of these two titrations. Also, both

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TABLE 1.2.  Correlation Matrix of Physical and Chemical Parameters for the Ford River from June 1983-October 1984.

| | ON | NI | AM | IN | TP | SI | Cl | CON | PH | Alk | Har | Tur | S.S. | Dis | D.O. | Tem |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Organic-N | 1.00 | | | | | | | | | | | | | | | |
| Nitrate-N | .18 | 1.00 | | | | | | | | | | | | | | |
| Ammonium-N | .13 | .05 | 1.00 | | | | | | | | | | | | | |
| Inorganic-N | .20 | .71* | .70* | 1.00 | | | | | | | | | | | | |
| Total P | .27 | .69* | -.16 | .30* | 1.00 | | | | | | | | | | | |
| Silica | .08 | -.16 | -.16 | -.16 | -.25 | 1.00 | | | | | | | | | | |
| Chloride | .20 | .30* | -.10 | .14 | -.001 | .50* | 1.00 | | | | | | | | | |
| Conductivity | -.22 | -.33* | -.11 | -.26 | -.22 | .45* | .07 | 1.00 | | | | | | | | |
| pH | -.28 | -.26 | .11 | -.05 | -.17 | .33* | .08 | .59* | 1.00 | | | | | | | |
| Alkalinity | -.28 | -.42* | -.04 | -.27 | -.34* | .49* | .11 | .90* | .71* | 1.00 | | | | | | |
| Hardness | -.23 | -.43* | -.03 | -.26 | -.35* | .50* | .13 | .90* | .66* | .99* | 1.00 | | | | | |
| Turbidity | .08 | -.61* | -.10 | .26 | .86* | -.23 | -.10 | -.19 | -.23 | -.31* | -.31* | 1.00 | | | | |
| Suspended solids | -.02 | .37* | .01 | .19 | .45* | -.66* | -.34* | -.30* | -.43* | -.43* | -.45* | .52* | 1.00 | | | |
| Discharge | .21 | .61* | .05 | .39* | .57* | -.42* | -.06 | -.71* | -.61* | -.82* | -.81* | .42* | .49* | 1.00 | | |
| Dissolved Oxygen | .22 | .26 | .03 | .15 | .23 | -.30* | -.002 | .71* | -.63* | -.66* | -.62* | .22 | .28 | .68* | 1.00 | |
| Water Temperature | -.35 | -.38* | .04 | -.20 | -.31 | .30* | -.007 | .79* | .71* | -.79* | .75* | -.30* | -.33* | -.75* | -.91* | 1.00 |

* Critical value (2-tailed t-test, p<0.05 = +/- 0.29)

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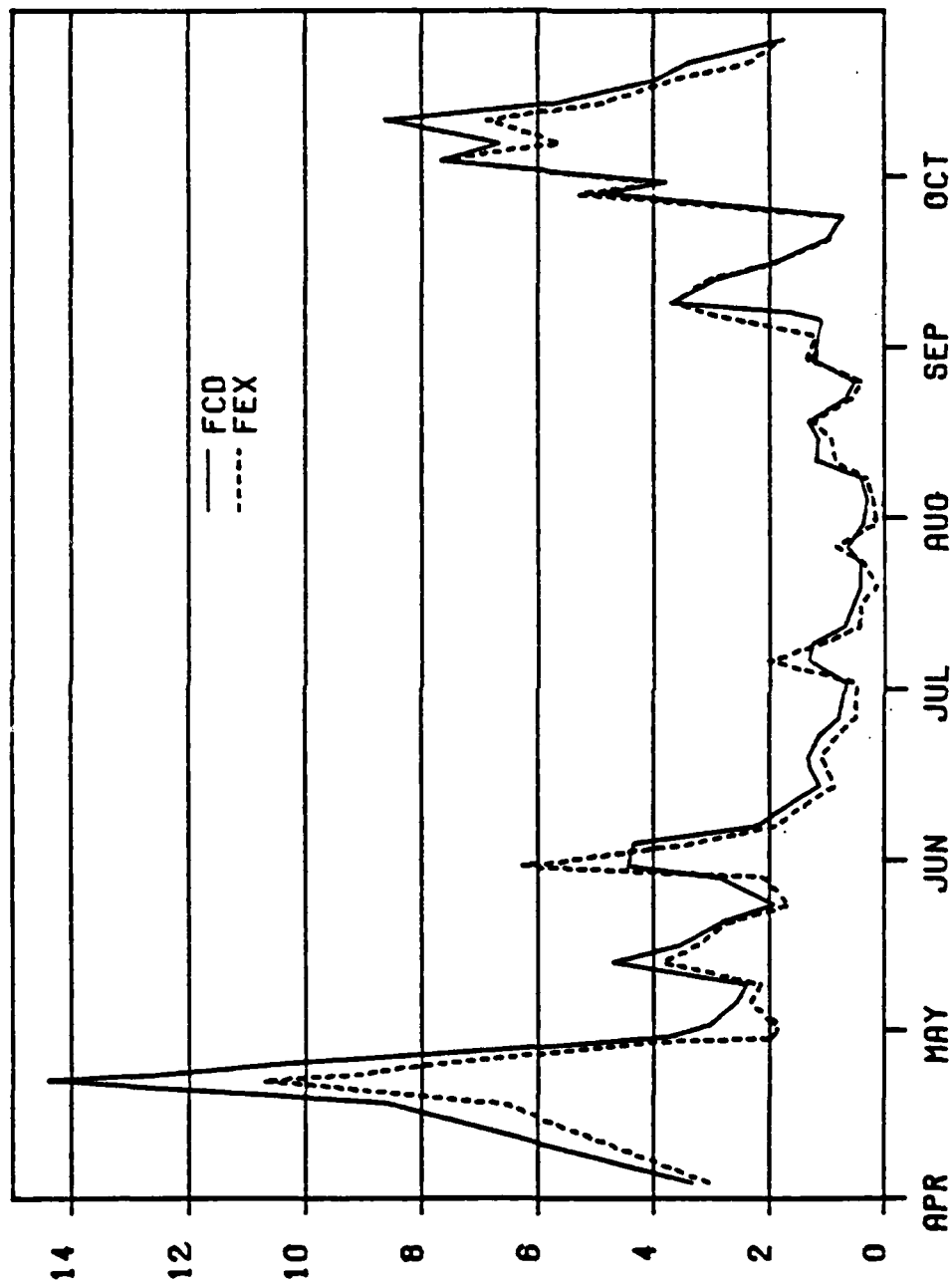
Figure 1.3. Discharge ($m^{-3}$ $sec^{-1}$) for the Ford River for 1984.

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TABLE 1.3. Alkalinity (mg CaCO$_3$/l) and Hardness (mg CaCO$_3$/l) for the Ford River. Values are monthly means $\pm$ SE, N in parentheses.

| | Control Site (FCD) | | Experimental Site (FEX) | |
|---|---|---|---|---|
| | Hardness | Alkalinity | Hardness | Alkalinity |
| OCT 1984 | 138 ± 5 (8) | 125 ± 5 (8) | 138 ± 5 (8) | 128 ± 7 (8) |
| NOV 1984 | 140 ± 0 (2) | 128 ± 0 (2) | 140 ± 0 (2) | 118 ± 0 (2) |
| DEC 1984 | 143 ± 0 (2) | 131 ± 1 (2) | 148 ± 3 (2) | 130 ± 1 (2) |
| JAN 1985 | 165 ± 1 (2) | 154 ± 1 (2) | 161 ± 1 (2) | 156 ± 1 (2) |
| FEB 1985 | 185 ± 1 (2) | 168 ± 1 (2) | 188 ± 1 (2) | 173 ± 0 (2) |
| MAR 1985 | 168 ± 1 (2) | 163 ± 0 (2) | 175 ± 1 (2) | 159 ± 0 (2) |
| APR 1985 | 98 ± 11 (6) | 89 ± 10 (6) | 99 ± 11 (6) | 88 ± 10 (6) |
| MAY 1985 | 112 ± 2 (10) | 101 ± 2 (10) | 107 ± 2 (10) | 98 ± 2 (10) |
| JUN 1985 | 134 ± 7 (8) | 120 ± 6 (8) | 125 ± 6 (8) | 121 ± 7 (8) |
| JUL 1985 | 167 ± 4 (10) | 158 ± 4 (10) | 165 ± 4 (10) | 162 ± 5 (10) |
| AUG 1985 | 166 ± 3 (8) | 154 ± 3 (8) | 162 ± 3 (7) | 152 ± 4 (8) |
| SEP 1985 | 143 ± 4 (10) | 131 ± 5 (10) | 139 ± 4 (10) | 127 ± 5 (10) |

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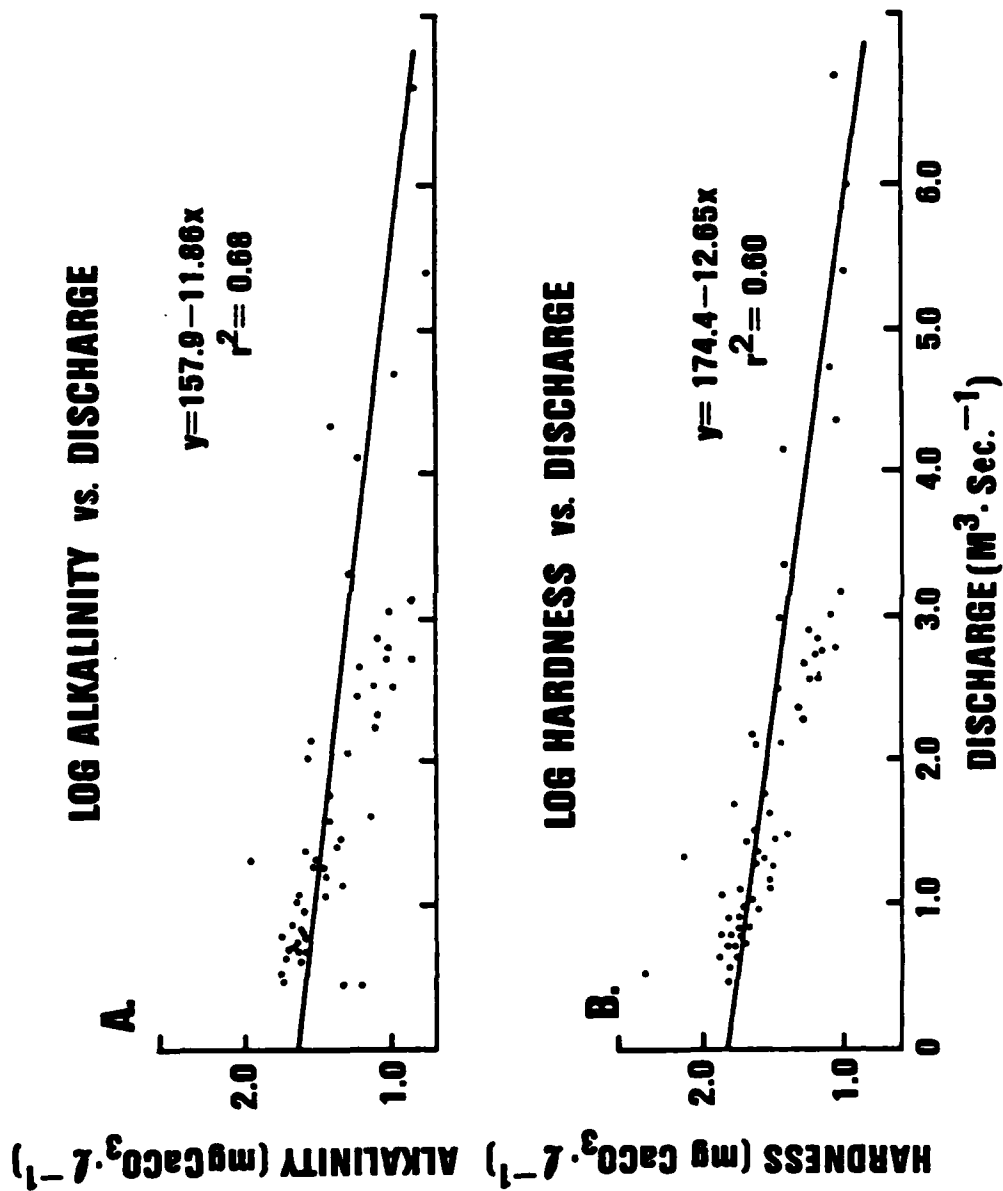
Figure 1.4. Plotted Regression Results of
(A) Log Alkalinity with Discharge and
(B) Log Hardness with Discharge

20

TABLE 1.4 Conductivity (umhos/cm) and Turbidity (NTU'S) for the Ford River. Values are Monthly Means $\pm$ SE, N in Parentheses.

| | Control Site (FCD) | | Experimental Site (FEX) | |
|---|---|---|---|---|
| | Conductivity | Turbidity | Conductivity | Turbidity |
| OCT 1984 | 174 ± 15 (4) | 1.0 ± 0.1 (7) | 167 ± 8 (4) | 0.9 ± 0.1 (7) |
| NOV 1984 | 200 (1) | 0.8 (1) | 165 (1) | 0.8 (1) |
| DEC 1984 | 189 (1) | 0.8 (1) | 188 (1) | 1.4 (1) |
| JAN 1985 | 245 (1) | 3.7 (1) | 180 (1) | 2.0 (1) |
| FEB 1985 | 220 (1) | 1.5 (1) | 232 (1) | 2.0 (1) |
| MAR 1985 | 238 (1) | 2.3 (1) | 230 (1) | 3.3 (1) |
| APR 1985 | 131 ± 14 (5) | 2.9 ± 0.6 (5) | 135 ± 17 (5) | 2.2 ± 0.4 (5) |
| MAY 1985 | 152 ± 4 (5) | 1.6 ± 0.3 (9) | 151 ± 5 (5) | 1.5 ± 0.4 (9) |
| JUN 1985 | 172 ± 16 (4) | 0.9 ± 0.1 (8) | 182 ± 18 (4) | 0.9 ± 0.1 (8) |
| JUL 1985 | 265 ± 4 (5) | 0.8 ± 0.1 (9) | 258 ± 8 (5) | 0.8 ± 0.1 (9) |
| AUG 1985 | 241 ± 11 (4) | 1.0 ± 0.2 (8) | 246 ± 17 (3) | 0.9 ± 0.1 (8) |
| SEP 1985 | 194 ± 8 (5) | 1.9 ± 0.4 (9) | 204 ± 9 (5) | 1.9 ± 0.5 (9) |

constituents are strongly correlated with conductivity (r=0.90, see Table 1.2) and could be predicted fairly precisely from this parameter alone.

Conductivity and turbidity were also essentially identical at FEX and FCD (Table 1.4). Again, trends in values were very similar to 1983 and 1984 data (see last annual report) with conductivity negatively correlated while turbidity was positively correlated with discharge (Table 1.2). Regressions were developed between these two parameters and discharge using log transformed data for conductivity (Figure 1.5) and by eliminating a few apparent outlier values for turbidity (Figure 1.6). The regression between log conductivity and discharge was reasonably robust ($r^2$ = 0.68, Figure 1.5), but even with removal of outliers, the regression between turbidity and discharge was weak (Figure 1.6) despite a significant correlation coefficient (Table 1.2). The lack of a strong correlation between turbidity and discharge may be related to the very low turbidity values typical of the Ford River even during high discharge conditions (Table 1.4, Figure 1.6).

Suspended solids and total dissolved solids values for 1985 (Table 1.5) continued the trends noted for the 1983 and 1984 data (last annual report). The two sites, FEX and FCD, had similar concentration trends for both parameters (Table 1.5). Suspended solids were not strongly correlated with discharge (Table 1.2) as is often the case for other rivers. This lack of a strong correlation results in a regression equation with a low $R_2$ (Figure 1.7). The low correlation coefficient may be related to the overall low values for suspended solids and to the fact that the preponderance of samples were collected during low flow periods (Figure 1.7).

Turbidity is also sometimes used to predict suspended solids values for rivers. Since the suspended solids loads were very low for the Ford River (Table 1.5) and since turbidity was also low (Table 1.4), the expected regression between the two parameters was not at all robust (Figure 1.8) even though the two were significantly correlated (Table 1.2). Certainly, both turbidity and suspended solids were well below levels which might be expected to cause problems for the biota (McKee and Wolf 1963). For example, McKee and Wolf reviewed studies that suggested that rainbow trout were not affected by 30 mg/l of suspended solids and only a few fish died at 90 mg/l. Values for the Ford River were generally well below 10 mg/l (Table 1.5). McKee and Wolf (1963) also suggested that turbidity values as high as 200 units were harmless to fish, whereas Ford River values were always less then 4 mg/l (Figure 1.6). Both turbidity and suspended solids were also low enough to cause only limited effect on light penetration. Thus, the apparent brown color of the Ford River is probably derived from dissolved organic carbon not from suspended matter. This brown color and an

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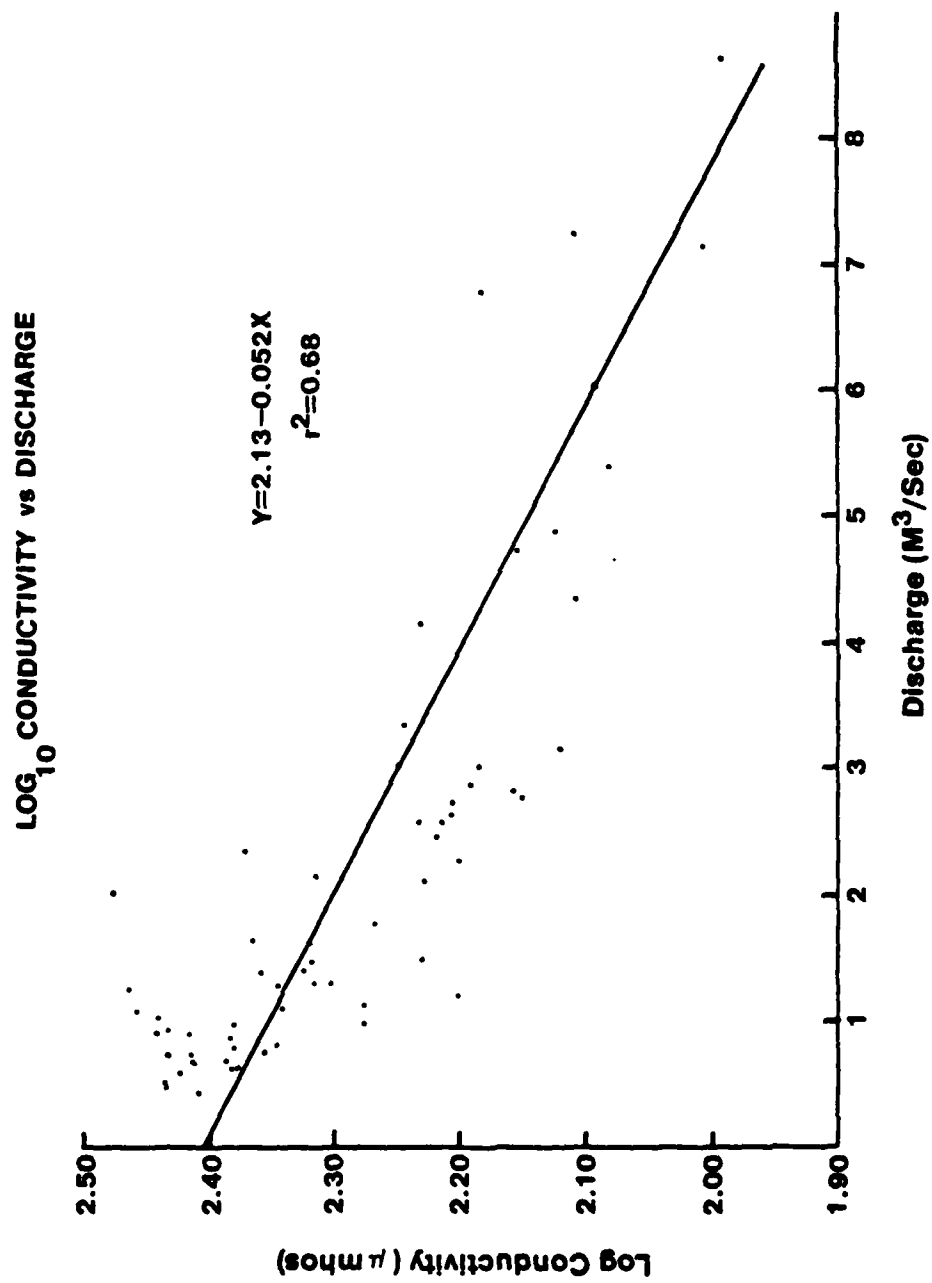
Figure 1.5. Regression Results of Conductivity with Discharge:
June 1983–June 1985.

Figure 1.6. Regression Results of Turbidity with Discharge: June 1983-June 1985.

TABLE 1.5 Suspended and Total Dissolved Solids (mg/l).
Values are Monthly Means $\pm$ SE, N in parentheses

| | Control Site (FCD) | | Experimental Site (FEX) | |
|---|---|---|---|---|
| | Suspended Solids | Total Dissolved Solids | Suspended Solids | Dissolved Solids |
| OCT 1984 | 1.3 ± 0.4 (7) | 191 ± 14 (7) | 1.1 ± 0.3 (7) | 210 ± 18 (7) |
| NOV 1984 | 2.4 (1) | 238 (1) | 3.5 (1) | 157 (1) |
| DEC 1984 | 1.2 (1) | 103 (1) | 0.8 (1) | 93 (1) |
| JAN 1985 | 1.0 (1) | 107 (1) | 0.5 (1) | 103 (1) |
| FEB 1985 | 0.6 (1) | 209 (1) | 0.8 (1) | 207 (1) |
| MAR 1985 | 1.4 (1) | 207 (1) | 2.7 (1) | 204 (1) |
| APR 1985 | 6.8 ± 1.2 (5) | 133 ± 12 (5) | 3.9 ± 1.1 (5) | 127 ± 11 (5) |
| MAY 1985 | 1.9 ± 0.3 (9) | 165 ± 9 (9) | 2.8 ± 1.1 (9) | 151 ± 5 (9) |
| JUN 1985 | 1.4 ± 0.2 (8) | 225 ± 63 (8) | 1.0 ± 0.2 (8) | 237 ± 27 (8) |
| JUL 1985 | 1.6 ± 0.2 (9) | 211 ± 10 (9) | 1.6 ± 0.4 (9) | 215 ± 10 (9) |
| AUG 1985 | 0.8 ± 0.2 (8) | 246 ± 26 (8) | 0.7 ± 0.1 (8) | 236 ± 22 (8) |
| SEP 1985 | 4.7 ± 1.9 (9) | 185 ± 5 (9) | 3.7 ± 1.5 (8) | 186 ± 4 (8) |
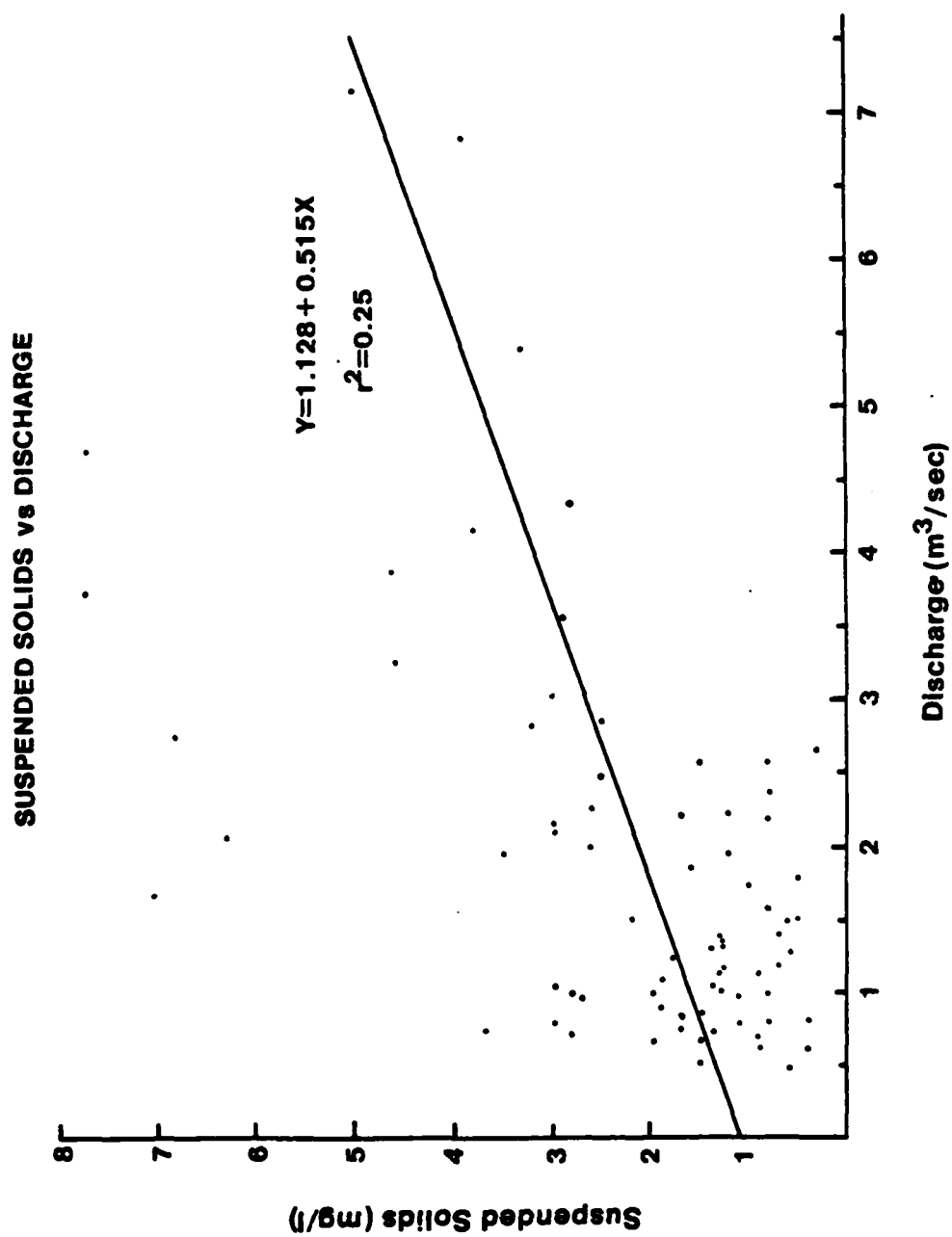
Figure 1.7. Regression Results of Suspended Solids with Discharge: June 1983–June 1985.

**TURBIDITY vs SUSPENDED SOLIDS**

Y=0.965+0.186X

$r^2=0.26$

Suspended Solids (mg/l)
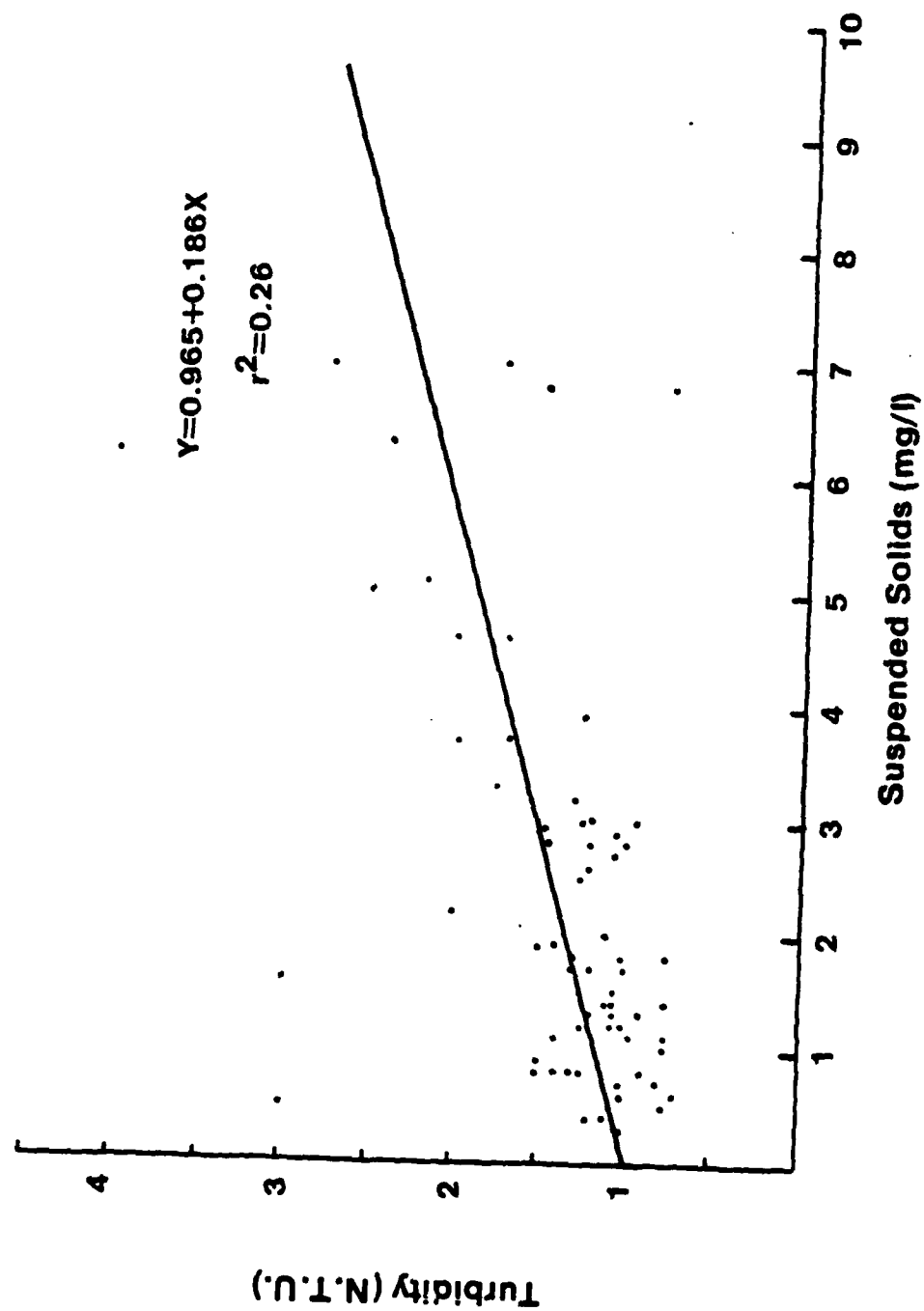
Turbidity (N.T.U.)

Figure 1.8.  Regression Results of Turbidity with Suspended Solids:
June 1983–June 1985.

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Table 1.6     Monthly Mean Values of Soluble Reactive Phosphorus and Total Phosphorus for the Ford River, 1984.

| | Control Site (FCD) | | | | Experimental Site (FEX) | | | |
|---|---|---|---|---|---|---|---|---|
| | Soluble Reactive P ug P/L | | Total P ug P/L | | Soluble Reactive P ug P/L | | Total P ug P/L | |
| JAN-MAR 1984 | | | 40 | (1) | | | 15 ± 3 | (2) |
| APR 1984 | | | 44 ± 14 | (5) | | | 22 ± 4 | (5) |
| MAY 1984 | | | 16 ± 2 | (9) | | | 20 ± 1 | (8) |
| JUN 1984 | 6 ± 0.8 | (4) | 23 ± 2 | (8) | 6.0 ± 0.3 | (4) | 13 ± 2 | (8) |
| JUL 1984 | 6 ± 0.5 | (9) | 24 ± 4 | (8) | 5 ± 0.5 | (9) | 18 ± 1. | (9) |
| AUG 1984 | 3 ± 0.2 | (9) | 36 ± 6 | (7) | 4 ± 0.2 | (9) | 21 ± 1 | (9) |
| SEP 1984 | 5 ± 0.3 | (8) | 31 ± 2 | (7) | 5 ± 0.2 | (8) | 24 ± 2. | (7) |
| OCT 1984 | 5 ± 0.2 | (7) | 22 ± 1 | (5) | 5 ± 0.2 | (7) | 16 ± 0.9 | (7) |
| NOV 1984 | | | 26 | | 4 | (1) | 15 | (1) |
| DEC 1984 | 4 | (1) | 31 | (1) | 6 | (1) | 20 | (1) |

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obvious, but unquantified, movement of sand and silt as bedload are much more likely to influence the biota than are either suspended solids or turbidity.

Nutrient chemistry results lag a year behind other parameters, since they are analyzed from frozen samples each winter after annual report preparation. The 1984 data for phosphorus (Table 1.6) were similar to 1983 data with soluble reactive P usually varying from about 4-6 ug P/l and total P varying from 10-40 ug P/l.

Since total phosphorus may be primarily derived from suspended soil particles, correlations between suspended solids on turbidity and total phosphorus often occurs. For the Ford River, a strong correlation exists for turbidity and total P (Table 1.2). A significant but weaker correlation exists between suspended solids and total P. Other positive correlations exist between total P and discharge, total P and nitrate while weak negative correlations occur between total P and temperature and between total P and alkalinity or hardness (Table 1.2).

In 1983, nitrogen chemistry appeared to differ slightly between FEX and FCD with total Kjeldahl N appearing to increase slightly in a downstream direction while ammonia appeared to decrease (see last annual report). The 1984 data did not support this apparent weak trend noted from the 1983 data (Table 1.7) There was little difference in either total Kjeldahl N or ammonium-N between the two sites in 1984 (Table 1.7). The nitrate-N data for 1984 (Table 1.7) coupled with data from 1983 (see last annual report) suggested a trend of higher values during the winter months of 100-200 mg N/l with low values of 15-25 mg N/l being typical of the growing season. Such seasonality is well known for streams.

Organic N was not correlated with any other parameter except for a weak, but statistically significant correlation with temperature (Table 1.2). Inorganic N was, of course, strongly correlated with its two major components, nitrate and ammonium, and was weakly but significantly correlated with discharge and total P. These latter two correlations were the result of relatively strong correlations of nitrate with total P and discharge since ammonium was not correlated with either parameter (Table 1.2). Nitrate was weakly but significantly positively correlated with both chloride and suspended solids and negatively correlated with conductivity, alkalinity, hardness, turbidity and temperature (Table 1.2). The negative correlation with temperature follows the known trend of streams to have high nitrate values during the non-growing season when uptake by terrestrial vegetation is at a minimum. Perhaps, some of the other correlations result from this same interaction.

Both phosphorus (especially soluble reactive phosphorus)

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TABLE 1.7 Ammonia-N (ug N/l), Nitrate-N (ug N/l), Nitrite-N (ug N/l) and Total Kjeldahl-N (mg N/l) for the Ford River for 1984. Values are Means $\pm$ SE, N in Parentheses.

CONTROL SITE (FCD)

| Month | $NH_4$-N | | $NO_3$-N | | $NO_2$-N | | Total Kjeldahl-N | |
|-------|----------|-----|----------|-----|----------|-----|------------------|-----|
| FEB | 59 | (1) | 323 | (1) | 5.0 | (3) | 1.11 | (1) |
| APR | 33 $\pm$ 5 | (5) | 52 $\pm$ 13 | (5) | 2.8 $\pm$ 0.2 | (5) | 1.17 $\pm$ 0.08 | (5) |
| MAY | 40 $\pm$ 3 | (9) | 17 $\pm$ 3 | (9) | 2.7 $\pm$ 0.1 | (9) | 0.90 $\pm$ 0.07 | (9) |
| JUN | 38 $\pm$ 5 | (8) | 17 $\pm$ 4 | (8) | 2.3 $\pm$ 0.2 | (8) | 1.18 $\pm$ 0.09 | (8) |
| JUL | 74 $\pm$ 2 | (8) | 22 $\pm$ 6 | (9) | 3.2 $\pm$ 0.5 | (8) | 1.04 $\pm$ 0.09 | (9) |
| AUG | 22 $\pm$ 4 | (9) | 20 $\pm$ 4 | (9) | 3.1 $\pm$ 0.3 | (9) | 0.91 $\pm$ 0.12 | (6) |
| SEP | 16 $\pm$ 1 | (1) | 18 $\pm$ 2 | (7) | 4.0 $\pm$ 0.2 | (7) | 0.98 $\pm$ 0.08 | (7) |
| OCT | 15 $\pm$ 1 | (6) | 37 $\pm$ 10 | (6) | 4.7 $\pm$ 0.3 | (6) | 0.95 $\pm$ 0.04 | (6) |
| NOV | 19 | (1) | 65 | (1) | 3.5 | (1) | 0.95 | (1) |
| DEC | 23 | (1) | 110 | (1) | 3.4 | (1) | 2.54 | (1) |

EXPERIMENTAL SITE (FEX)

| Month | $NH_4$-N | | $NO_3$-N | | $NO_2$-N | | Total Kjeldahl-N | |
|-------|----------|-----|----------|-----|----------|-----|------------------|-----|
| FEB | 47 | (1) | 172 | (1) | 2.1 | (1) | 0.88 | (1) |
| APR | 21 $\pm$ 1 | (5) | 67 $\pm$ 19 | (5) | 2.1 $\pm$ 0.2 | (5) | 1.02 $\pm$ 0.04 | (5) |
| MAY | 29 $\pm$ 5 | (8) | 15 $\pm$ 3 | (8) | 2.0 $\pm$ 0.3 | (8) | 1.00 $\pm$ 0.05 | (8) |
| JUN | 24 $\pm$ 3 | (8) | 15 $\pm$ 2 | (8) | 1.9 $\pm$ 0.2 | (8) | 1.07 $\pm$ 0.06 | (8) |
| JUL | 28 $\pm$ 4 | (9) | 20 $\pm$ 2 | (9) | 2.2 $\pm$ 0.2 | (9) | 0.96 $\pm$ 0.04 | (9) |
| AUG | 16 $\pm$ 1 | (9) | 24 $\pm$ 8 | (9) | 3.4 $\pm$ 0.2 | (9) | 0.75 $\pm$ 0.06 | (9) |
| SEP | 16 $\pm$ 1 | (8) | 16 $\pm$ 3 | (8) | 4.4 $\pm$ 0.3 | (8) | 0.99 $\pm$ 0.09 | (7) |
| OCT | 19 $\pm$ 2 | (7) | 21 $\pm$ 5 | (7) | 4.4 $\pm$ 0.3 | (7) | 0.82 $\pm$ 0.08 | (7) |
| NOV | 35 | (1) | 59 | (1) | 3.7 | (1) | 0.65 | (1) |
| DEC | 43 | (1) | 109 | (1) | 4.4 | (1) | 0.47 | (1) |

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TABLE 1.8. Chloride (mg Cl/1) and Dissolved Silica (mg Si/1) for the Ford River for 1984. Values are Monthly Means $\pm$ SE, N in Parentheses.

| Month | Control Site (FCD) | | Experimental Site (FEX) | |
|---|---|---|---|---|
| | Chloride | Silica | Chloride | Silica |
| JAN | — | 10.3 (1) | 3.5 (1) | — |
| FEB | 2.7 (1) | 9.5 (1) | 3.1 (1) | 10.5 (1) |
| MAR | — | 10.7 (1) | 3.5 (1) | 10.5 (1) |
| APR | 2.9 ± 0.6 (5) | 7.6 ± 0.8 (5) | 2.3 ± 0.1 (5) | 8.6 ± 1.1 (4) |
| MAY | 2.6 ± 0.1 (9) | 6.9 ± 0.3 (5) | 2.6 ± 0.1 (8) | 7.1 ± 0.8 (8) |
| JUN | 3.3 ± 0.4 (8) | 8.8 ± 0.2 (8) | 3.2 ± 0.3 (8) | 8.8 ± 0.2 (8) |
| JUL | 3.5 ± 0.5 (8) | 9.9 ± 0.1 (9) | 3.2 ± 0.3 (9) | 9.9 ± 0.2 (8) |
| AUG | 3.2 ± 0.1 (9) | 10.4 ± 0.1 (9) | 3.8 ± 0.2 (9) | 10.7 ± 0.1 (9) |
| SEP | 3.4 ± 0.1 (7) | 10.2 ± 0.1 (7) | 3.9 ± 0.2 (8) | 10.2 ± 0.2 (7) |
| OCT | 3.9 ± 0.4 (6) | 10.2 ± 0.1 (7) | 4.2 ± 0.4 (7) | 9.9 ± 0.1 (7) |
| NOV | 3.3 (1) | 10.1 (1) | 3.6 (1) | 10.6 (1) |
| DEC | 3.3 (1) | 10.5 (1) | 3.8 (1) | 10.3 (1) |

**SOLAR RADIATION**
**FCD – 1986**
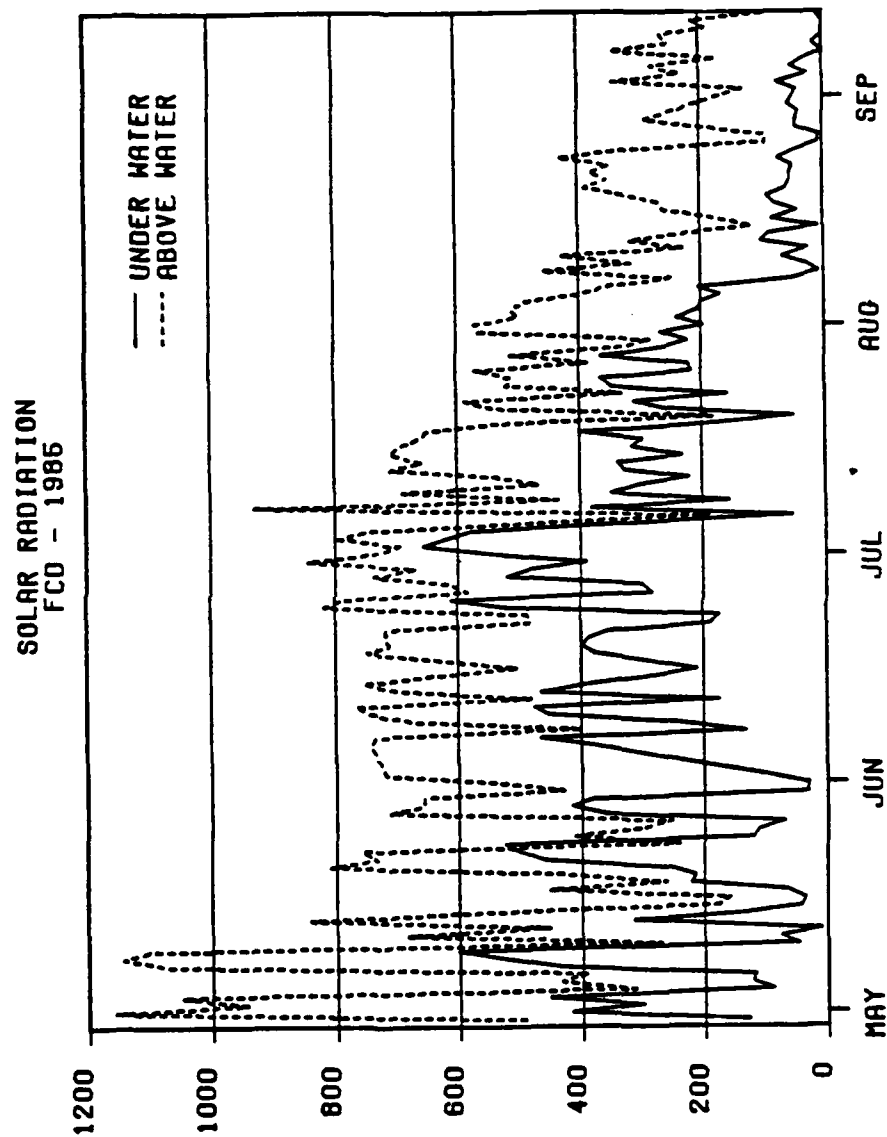
Figure 1.9. Average Daily Above Water Photosynthetically Active
Radiation ($\mu E \cdot S^{-1} \cdot M^{-2}$) for the 1000-1400 Hour Period
for the Ford River Control Site.

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(Table 1.6) and inorganic nitrogen (Table 1.7) were present
at concentrations low enough to potentially limit plant
production during low flow periods in summer months.
Correlations between these parameters and periphyton density,
chlorophyll a and organic matter accrual rates will be
presented in element 2.

As in 1983 (see last annual report), chloride and
dissolved silica for 1984 were not significantly different
between the two sites (Table 1.8). Both constituents vary
over fairly narrow ranges. Combined data for both 1983 and
1984 showed that chloride only varied from 2-5 mg Cl/l, while
dissolved silica usually varied from 6 to 11 mg Si/l. Silica
was weakly positively correlated with chloride, conductivity,
pH, hardness, alkalinity, and temperature (Table 1.2) and
negatively correlated with suspended solids, discharge, and
dissolved oxygen (Table 1.2). Chloride was weakly but
positively correlated only with silica and nitrate with no
other correlations of note existing (Table 1.2).

All automatically monitored data from 1983 and 1984 have
been summarized and daily averages for most of the growing
season are available for both years. These data have been
used in correlations with biotic data in the following
elements and will not be reported here. An example of the
type of data available is the solar radiation data (Figure
1.9).

In conclusion, ambient monitoring data are available to
fulfill the objectives for this element. These data show
that FCD and FEX are very comparable sites with only minor
differences from site to site. These data also demonstrate
the excellent water quality of the Ford River. These data
have been used in the biotic monitoring program with
correlations between periphyton, insects, and fish and
appropriate ambient monitoring data having been examined.
Some of these correlations will be presented in the
following elements. The correlations between various
physical and chemical parameters reported in this element
will be useful in interpreting the results of correlations
between ambient monitoring and biotic parameters.

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Element 2 - <u>Monitoring of Species Composition, Numbers,
Diversity, Biomass Production, Cell Volume, and
Chlorophyll a / Phaeophytin a Production for
Periphyton</u>

Changes from workplan - None.

Objectives

        The objectives of the periphytic algal studies are:
        (1) to quantify any changes in species diversity,
            species density, species evenness, species
            richness and cell density that occur as a result
            of ELF electromagnetic fields,
        (2) to quantify any changes in primary productivity
            that might occur as a result of ELF
            electromagnetic fields,
        (3) to monitor any changes in chlorophyll <u>a</u> and
            organic matter accrual rates as a result of
            ELF electromagnetic fields, and
        (4) to determine algal cell volumes and chlorophyll <u>a</u>
            to phaeophytin a ratios, thereby providing
            indices of physiological stress in periphytic
            algal cells that might occur as a result of
            ELF electromagnetic fields.

Rationale

        Structural Community indices:  Community composition of
the attached algae has often been used by researchers to
indicate subtle or dramatic changes in water quality.  The
effects of toxicants, nutrients, or other pollutants has
often been linked to changes in abundances of particular
diatom species and often to the presence or absence of
sensitive species.  The use of a species diversity index
coupled with measurements of species evenness and richness
allows between site comparisons of attached algal communities
which will include the subtle shifts in species composition
that may potentially occur as a result of ELF radiation.  The
dominant diatom community which develops on exposed glass
slides often consists of 50-70 species on a single slide out
of an estimated species pool for the Ford River of over 300
total species.  The potential changes in species abundance,
species diversity and species evenness of this community
afford sensitive and statistically measurable parameters
against which to measure seasonal variation, site variation,
yearly variation and potential ELF effects.

        In addition to studying the species composition of the
attached algae we are examining the relatively simple
parameter of overall cell density.  This directly determined
density measure represents the numerical end product of

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species succession and abundance or dominance shifts by individual species in the attached algae community, and also includes the effects of physical environmental factors. The use of cell density, which is affected by both biological and physical factors, may thus reveal changes due to ELF effects. This single parameter, while perhaps less sensitive to small disturbances, is a very important correlate with other estimates of production such as chlorophyll a, or organic matter accrual. This labor intensive direct counting procedure is thus the yardstick against which other production estimates are often compared and should help separate potential ELF induced effects from other biological or physical influences.

Functional Community Indices: Measurement of the amounts of chlorophyll a, the primary photosynthetic pigment used by all algae, affords both quantitative and qualitative comparisons between sites. The quantity of chlorophyll a present can be directly measured through intensity of fluorescence and can be correlated with cell density and cell volume to indicate the relative or qualitative physiological state of the algal community. Subtle effects of ELF electromagnetic fields on the photosynthetic pigments may result in cellular "leaking" or a general physiological weakening of individual cells. This weakening may decrease both the total quantity of chlorophyll a present as well as reduce the amount of oxygen generated through photosynthesis. Including the ratios of the main chlorophyll a degradation product, phaeophytin a, can also indicate the degree of physiological stress in the algal community. Site comparisons of the relative amounts of oxygen produced by the attached algae will then compare the final results of photosynthesis.

This multiple approach of methodologies couples direct determinations of quantities of pigments present, with indirect physiological measurements of pigment condition, with further direct measurements of oxygen levels produced by that pigment. These parameters thus allow statistical comparisons of production between sites throughout the year. Utilizing several different approaches allows us to continue analyses throughout the winter time when we rely more on measuring chlorophyll a and organic matter accrual to provide estimates of production, since the more detailed production studies are not feasible.

Our rationale has thus been to provide multiple data sets taken independently, incorporating several methodologies in order to detect and separate any "real" differences as a result of ELF electromagnetic radiation.

Materials and Methods

Plexiglass slide racks were designed to hold 8 or 10 standard 7.6 x 2.5 cm glass slides in a vertical placement oriented facing the current in the river. These slide racks were fastened to bricks and placed in riffle habitats at the

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control (FCD) and experimental sites (FEX). Slides were removed after 14 days for chlorophyll $\underline{a}$, phaeophytin $\underline{a}$, and organic matter biomass accrual rates and after 28 days for chlorophyll $\underline{a}$, phaeophytin $\underline{a}$ and organic matter standing crop determination and for counts of algal cells for determination of density, species diversity, evenness and for determination of cell volumes. Ten slides were sampled for analysis of chlorophyll $\underline{a}$ and organic matter accumulation at each sampling interval and 5 slides were sampled for cell counts and cell volume determination after 28 days.

For species composition, cell counts, and cell volume determinations, 5 slides were removed on each sampling period from each habitat. Three slides were air dried and the other two were placed in a mixture of 6 parts water, 3 parts 95% ethanol and 1 part formalin. The air dried slides were later scraped in the lab with razor blades to remove the diatoms for further specimen cleaning and slide preparation. The other two slides were used to determine species compositon of non-diatom algae.

Slides were prepared for specimen identification by cleaning the diatoms removed from the exposed glass slides in concentrated hydrogen peroxide (30%) followed by further oxidation of the cellular contents with the addition of small amounts of potassium dichromate (Van der Weff 1955). The cleaned diatoms were then rinsed with distilled water and settled in graduated cylinders. The final volume of concentrate containing the cleaned diatom frustules was then measured and 1 ml subsamples pipetted onto 22 $mm^2$ coverslips, until an adequate counting density was achieved. The coverslips were air dried and permanently mounted on glass slides using Hyrax® medium.

Counting was done at 1250 X magnification on a Zeiss microscope equipped with phase contrast illumination and an oil immersion 100 X NEOFLUAR phase objective with numerical aperture of 1.30. Transects were taken moving across the coverslip until between 250-450 frustules were counted. Estimates of diatom densities were made from quantitative samples via the equation:

$$\text{cells } m^{-2} =$$

(Valves counted) $(mm^{-2}$ of coverslip) (ml of concentrate)

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$2(mm^{-2}$ counted) (ml of subsample) $(m^{-2}$ of slide surface)

Diatom species composition was recorded for the 250-450 frustules for determination of species richness, diversity using the Shannon-Wiener formula (Southwood 1978), evenness, and dominance. Cell volume measurements were taken by measuring lengths, widths and depths and recording shapes of dominant diatoms for later calculation of cell volume based

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on formulae for combinations of various geometric shapes.

During 1985, ten slides were taken for chlorophyll $a$ and phaeophytin $a$ determinations for each exposure period from at each site. Analyses for both chlorophyll $a$ and phaeophytin $a$ followed the fluorometric determination described in Method 1003C in Standard Methods (APHA 1980). All samples were analyzed within a month of collection. Initial analyses suggested that there were no differences in chlorophyll $a$ and phaeophytin $a$ between samples where the cells had been scraped from the slide and ground to facilitate cell rupture and samples with the grinding step eliminated. Subsequently, slides were collected, frozen for at least 24 hours to promote cell rupture, and extracted in 90% buffered acetone. Chlorophyll $a$ and phaeophytin $a$ were then determined following procedures outlined in Standard Methods.

During 1985, ten slides were also taken at each site for organic matter biomass determination. Analyses were conducted following procedure 1003D for productivity estimates in Standard Methods (APHA 1980). While using the gain in ash-free dry weight per unit area as a measure of net production (APHA 1980), we realize that determining rates of primary production from a temporal series of biomass measurements results in minimal estimates of net production. The losses that may occur from excretion of organic compounds, respiration, mortality, decomposition, emigration, or grazing are not included in determining this production estimate (Wetzel 1975). The accrual of biomass is a combination of processes involving dynamics of both colonization and production. Results from our study of the colonization component on biomass accrual, in addition to data from future studies designed to examine the impact of immigration and grazing on biomass accrual, should, increase the accuracy of these production estimates. Rather than list results as production, we will refer to them as organic matter accrual rates.

All 1985 slide samples were frozen and analyzed within 30 days of collection time. Early 1983 samples were more variable than later samples since invertebrates were not all removed before ash-free dry weight determination. This problem was rectified in June, 1983, and all data subsequent to that time are of organic matter on slides after removal by hand of visible invertebrates such as black flies from the slides.

Statistical comparisons between sites for the 1984-85 report included one way analyses of variance and paired t-tests contrasting the 28 day samples of chlorophyll $a$, organic matter, and cell densities between the experimental and control sites. In addition paired t-test comparisons were made of the calculated indices of species diversity and

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species evenness between sites. The completion of the diatom
volume computer program this fall also provided information
on the total biovolume of all diatom cells on the glass
slides for each site. This additional parameter was also
statistically tested between sites for 1984-85 and will soon
be expanded to calculate earlier biovolumes from previous
years as well. Another new parameter investigated in detail
this year was the average individual diatom cell volume.
These two new parameters, individual cell volume, and
biovolume provided additional information from correlations
with other biological data, such as chlorophyll $\underline{a}$ or biomass
levels at both sites.

While we increased the complexity and sophistication of
our statistical methods during 1985 over those of the last
report, the inherent variability between samples was still
high. For example, cell density, chlorophyll $\underline{a}$ and biomass
accruals had coefficients of variation (C.V.'s) between
10-110% for 1983-84 (see last annual report, AE-031). In an
effort to reduce this variability, increased sample numbers
were taken during 1984-85. The number of samples required
for a precise, single time point comparison was still
prohibitively large (more than twenty five samples or slides
of each parameter). This number of samples was too costly
and too labor intensive to be practical. However,
chlorophyll $\underline{a}$ and organic matter samples were increased to 10
per sample data. This increased effort reduced the range of
the C.V.'s for chlorophyll $\underline{a}$ to between 4-88%, with an
average or 32% and for organic matter to between 11-93%, with
an average of 40%. Cell density estimates were based on 3
slides per sample date and had a C.V. range between 3-115%,
with an average of 38%. All three important biological
parameters, thus showed an average C.V. at or below 40%.
Derived measurements of species diversity or species evenness
showed much smaller C.V. ranges of between 1-27%, with
averages of 10% and 6.6% for species diversity and evenness.
The individual C.V.'s observed for our monthly samples of
biological parameters often fell below the 20% level commonly
used in benthic studies (Cummins 1975), and statistical
comparisons made between sites at such times therefore
provided a sample size sufficient to be 95% certain of
detecting a 40% difference in means between the two sites at
the .05 significance level (Sokal and Rohlf 1969).

The abilities of both water chemistry parameters and
environmental conditions to predict levels of biological
variables were investigated through the use of extensive
multiple regression analyses. All data obtained after final
site selection in June 1983 through June 1985 were analyzed.
In addition, all ambient data from the $\underline{in\ situ}$ probes and
recorders were summarized and included in similar multiple
regression comparisons for June 1983-June 1985. The use of
multiple regressions together with correlation matrices often
indicate potential interrelationships between physical,

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chemical, or biological parameters. The combination of all
biological data since June 1983 also provided the first
opportunity to expand from the two way analyses of variance
of our last report to a more complete 3-way ANOVA.
Comparisons of chlorophyll $\underline{a}$, organic matter, and diatom cell
densities were made across years, sites, and sample periods.
This comparison provided the ability to statistically detect
any major differences between the studied parameters due to
potential ELF effects. As more date become available, the
use of a time series analyses may also be used. The
application of these more sophisticated testing procedures
should reduce the strong influences of seasonality or time of
sampling which appear as significant factors affecting
virtually all biological parameters (see 3-way ANOVA
results).

## Results and Discussion

### A. Colonization Patterns

In two previous annual reports (AE-020 and AE-031 for
1982/1983 and 1983/1984), we summarized data on colonization
patterns for periphyton for the Ford River. These data
demonstrated that a 14 day sampling period was reasonable
during the active growing season (mid June to mid September)
for estimates of daily chlorophyll $\underline{a}$ productivity and rates
of organic matter accumulation for the Ford River. This 14
day period coincided with the period of rapid increases in
chlorophyll $\underline{a}$, phaeophytin $\underline{a}$, and accrual of organic matter
on slides. Thus, it minimized losses due to sloughing, etc.
that increase as the periphyton community "matures" or
approaches its maximum sustainable density on the slides
(Burton and King 1983.) This period of maximum daily
increase in organic matter and chlorophyll $\underline{a}$ is often used as
a measure of net production (APHA 1980; Burton and King
1983). Since the period of maximum daily increase was
prolonged during cold weather, we used the 28 day period for
estimates of daily productivity or accrual rate during the
winter months and the 14 day period from April through
October.

After 14-21 days during periods with temperatures above
15°C, data from the last annual report (AE-031) showed that
the community composition changed slowly through time and
qualitatively approximated the mature community on natural
substrates in the stream. Thus, standing crop estimates of
chlorophyll $\underline{a}$, phaeophytin $\underline{a}$, organic matter, and all
community composition parameters (density, species diversity,
species evenness, and species dominance) are based on a 28
day sampling program throughout the year. All 1985 data were
based on this 14 and/or 28 day sampling regime. As reported
in the 1982/83 annual report (AE-020), differences between
pool and riffle habitats were either slight or insignificant.
Thus, all samples are presently collected from riffle areas

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only. Pool and riffle data from 1983 were pooled for the following comparisons of 1985 data with 1983 and 1984 data.

## B. Annual Patterns for Chlorophyll a

The 28 day standing crop data for chlorophyll a (Fig. 2.1) continued to show the high year to year variability previously reported (see Annual Report AE-031). In 1985, standing crop remained low (below 2 mg $m^{-2}$) throughout most of the year with a minor peak in June of about 3 mg $m^{-2}$ and major peaks of 7-9 mg $m^{-2}$ in August (Fig. 2.1). The only consistency between the summers of 1983, 1984, and 1985, was this July-August peak. However, it varied in magnitude from values as high as 13-15 mg $m^{-2}$ in 1983 to as low as 4-7 mg $m^{-2}$ in 1984 to the intermediate values of 1985. The April bloom of 2-5 mg $m^{-2}$ that occurred just after snow melt in 1984 did not occur in 1985 (Fig. 2.1). The minor June peak in 1985 (Fig. 2.1, note lack of FEX data for June -lost due to vandalism) was comparable to June values for 1984. Winter values for 1983-4 and 1984-5 were always low (1 mg $m^{-2}$ or less).

Daily accrual rates for chlorophyll a (Figure 2.2) followed the same trend as did standing crop (Figure 2.1). A small fall peak (58-68 ug $m^{-2}day^{-1}$) in November declined to overwinter lows of less than 40 ug $m^{-2}$ $day^{-1}$ with the July-August peak approaching 120 ug $m^{-2}day^{-1}$ (Figure 2.2). Peak values for the July-August peak were about half of those reported for 1983 (216-336 ug $m^{-2}day^{-1}$) and slightly higher than the 94-95 values reported for 1984. The peak for 1984 of 118-121 ug $m^{-2}$ $day^{-1}$ that occurred in May was higher than May values for 1985. Like standing crop, the only consistency between the summers of 1983, 1984, and 1985 was the July-August peak.

The lack of an April-May bloom in 1985 as compared to 1984 was probably related to the magnitude of floods during this period. Peak discharge during this period in 1984 was 7 $m^{-3}sec^{-1}$ while peak discharge in 1985 was 14 $m^{-3}sec^{-1}$ (see Figure 1.3). During this flood period in 1985, daily accrual rates for chlorophyll a dropped to 3-6 ug $m^{-2}day^{-1}$, while accrual rates during the flood period of 1984 only decreased to 13-14 ug $m^{-2}day^{-1}$.

Careful placement of slides with respect to flow rate (Table 2.1), shading, depth, etc. resulted in comparable results from both the control (FCD) and experimental sites (FEX) (Table 2.2). This lack of statistically significant differences between sites for chlorophyll a contrasts with our previous results which showed strong site differences in 1983 and 1984.

Results from 3 way ANOVA analyses for data collected

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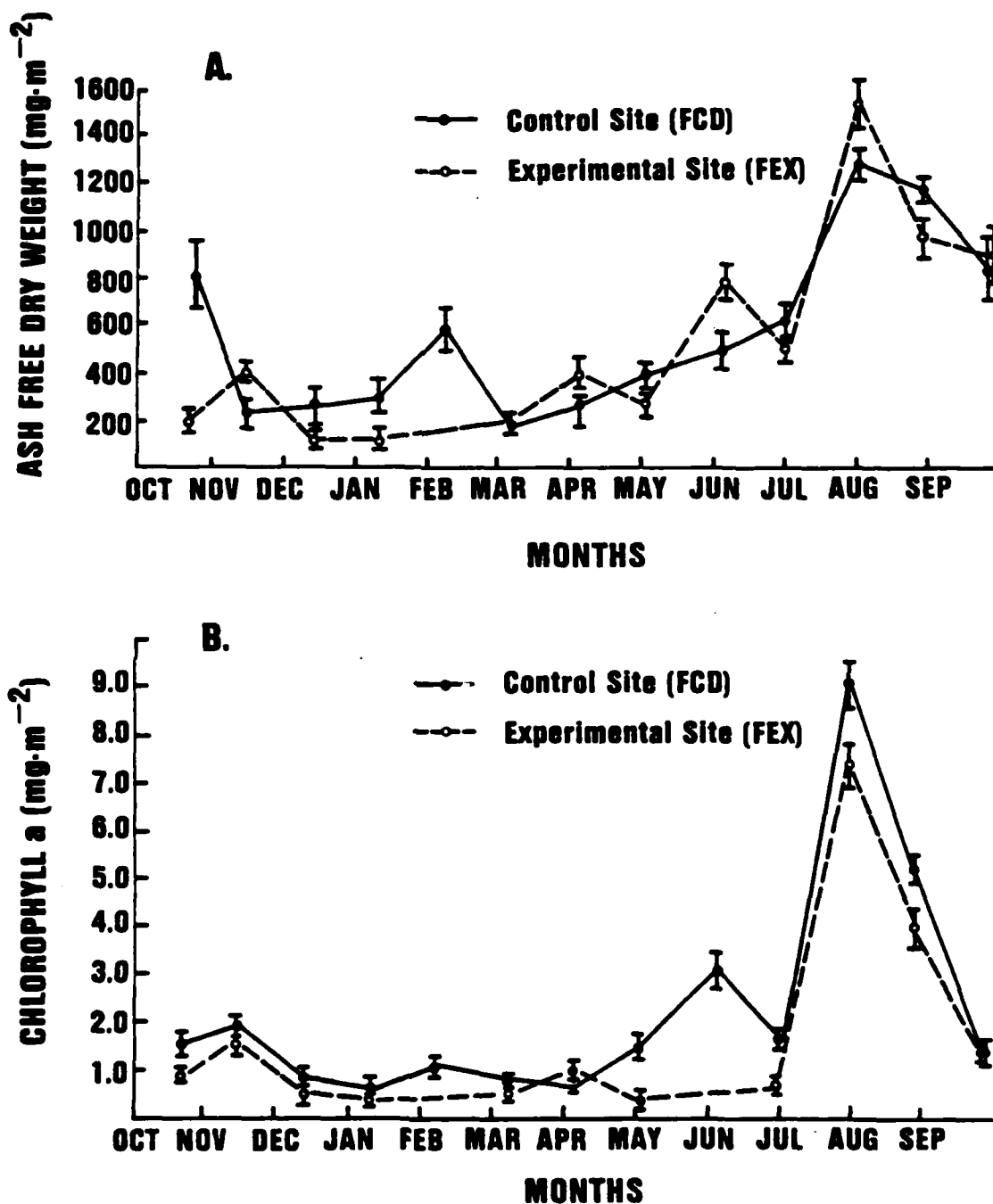
FIGURE 2.1. Standing Crop of Organic Matter (AFDW) and
Chlorophyll a for 28 Day Exposed Glass
Slides for 1984-85. N=10 Except on 1/9/85
(5 for both sites for both parameters) and
N=9 for FCD for Organic matter on 9/29/85.
Note Missing Data for Chlorophyll a for FEX
on 2/6 and 6/3/85.

TABLE 2.1. Stream Velocities (m/sec) Taken at the Periphyton Samplers on the Ford River in 1985. Values are Monthly Means $\pm$ SE, N in Parentheses.

|  | Ford Control Site | | Ford Experimental | |
|---|---|---|---|---|
| April | 0.300 | (1) | 0.389 | (1) |
| May | 0.449 $\pm$ 0.02 | (5) | 0.473 $\pm$ 0.02 | (5) |
| June | 0.407 $\pm$ 0.02 | (2) | 0.457 $\pm$ 0.06 | (2) |
| July | 0.323 $\pm$ 0.05 | (4) | 0.343 $\pm$ 0.03 | (3) |
| August | 0.343 $\pm$ 0.09 | (2) | 0.340 $\pm$ 0.02 | (3) |
| September | 0.433 $\pm$ 0.01 | (3) | 0.437 $\pm$ 0.02 | (3) |

from the two year period ending on June 3, 1985, indicated a significant site effect ($p < 0.05$, Table 2.3) for chlorophyll a. We suspect that this significant effect was related to differences in slide placement between sites in 1983 as previously reported (see last annual report). Results of paired t-tests for 1985 alone indicate agreement with these previous results (Table 2.6). We are encouraged that a majority of the site variability may be explained by time of sampling and may be partitioned out when examined seasonally, rather than combining data across a year's time. Results from the 3 way ANOVA indicated a strong interaction with sample date and year being very significant (Table 2.3), with sample date providing the single most significant source of variation.

## C. Annual Patterns of Organic Matter Standing Crop and Accrual

Standing crop of organic matter expressed as ash free dry weight (AFDW) in 1985 was characterized by winter lows of 163-309 mg $m^{-2}$ AFDW with fairly steady increases beginning in March and culminating in peak values of 1320-1568 mg $m^{-2}$ in late July (Figure 2.1). This pattern was in sharp contrast to the multiple peaks throughout the year reported for the 1983 and 1984 (see last annual report, AE-031). Nevertheless, results for the two sites were very similar (Figure 2.1) with no significant difference occurring between the control (FCD) and experimental (FEX) sites (Table 2.2 and 2.6). This lack of significant differences between sites for 1985 continued the trends reported for 1983 and 1984 (Table 2.3 and see last annual report).

Daily accrual rates of AFDW followed the same trend as standing crop data (Figure 2.2) with the exception of a peak in accrual rates, especially for FCD, in October, 1984. Again, there were no significant differences between sites for 1985 data (Table 2.2).

The consistent July-August peak apparent for chlorophyll a also occurred for organic matter for both standing crop (Figure 2.1) and to a lesser extent for daily accrual rate (Figure 2.2). This July-August low flow peak was also characteristic of 1983 and 1984 (see last annual report). In fact, peak standing crop values for organic matter AFDW were much more consistent than were values for chlorophyll a. In 1983, AFDW peaked at 1267-1410 on July 25 and remained at levels of 1013-1147 through August 22; in 1984, peak values were approached on July 30 (1019-1128) but were reached on August 27 at 1176-1425 mg $m^{-2}$. In 1985, peak values of 1320-1568 were reached on July 29, and remained at levels of 1013-1213 through August 26 (Figure 2.1). Daily accrual rates for these periods followed the same trend, although actual peak values showed more year to year variability (Figure 2.2 and last annual report) There were significant

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TABLE 2.2: ANOVA Comparisons of 28 day Chlorophyll a and Organic Matter Standing Crops and 14 day Accrual Rates for the Experimental Site(FEX) and Control Site (FCD) from October 1984–September 1985.

| | | | | |
|---|---|---|---|---|
| **CHLOROPHYLL-a STANDING CROP** | | | | |
| Source of Variation | df | ss | ms | $F_s$ |
| Between sites | 2 | 1.94 | 1.94 | 0.36 NS |
| Within Sites | 22 | 118.52 | 5.39 | |
| **CHLOROPHYLL-a ACCRUAL** | | | | |
| Source of Variation | df | ss | ms | $F_s$ |
| Between sites | 2 | 590.47 | 590.47 | 0.38 NS |
| Within sites | 21 | 32,809.26 | 1562.35 | |
| **ORGANIC MATTER STANDING CROP** | | | | |
| Source of Variation | df | ss | ms | $F_s$ |
| Between sites | 2 | 7,377.56 | 7,377.56 | 0.05 NS |
| Within sites | 23 | 3,754,865.08 | 163,255.00 | |
| **ORGANIC MATTER ACCRUAL** | | | | |
| Source of Variation | df | ss | MS | $F_s$ |
| Between sites | 2 | 16.35 | 16.35 | 0.21 NS |
| Within sites | 21 | 1645.87 | 78.38 | |

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TABLE 2.3. Three Way ANOVA Comparisons of Two Years, Two Sites and 13 Sample
Periods for Chlorophyll a, Biomass, and Cell Density (Data from
6-27-83 through 6-3-85) For the Ford River.

## CHLOROPHYLL a

| Source of Variation | df | ss | ms | $F_s$ |
|---|---|---|---|---|
| Year | 1 | 44.38 | 44.38 | 28.45 ** |
| Site | 1 | 14.02 | 14.02 | 8.99 * |
| Sample Date | 12 | 391.62 | 32.63 | 20.90 *** |
| Year X Site | 1 | 0.60 | 0.60 | <1.00 NS |
| Year X Sample Date | 12 | 121.52 | 10.13 | 6.49 ** |
| Site X Sample Date | 12 | 37.17 | 3.10 | 1.99 NS |
| Year X Site X Sample Date | 12 | 18.73 | 1.56 | |
| | 51 | 628.0 | | |

F.05 [1,12]= 4.75; F.001 [1,12]=18.6; F.01 [12,12]=4.16; F.001 [12,12]=7.00

## BIOMASS

| Source of Variation | df | ss | ms | $F_s$ |
|---|---|---|---|---|
| Year | 1 | 0.248 | 0.248 | 14.59 ** |
| Site | 1 | 0.055 | 0.055 | 3.24 NS |
| Sample Date | 12 | 4.138 | 0.345 | 20.29 *** |
| Year X Site | 1 | 0.139 | 0.139 | 8.18 * |
| Year X Sample Date | 12 | 0.973 | 0.081 | 4.76 ** |
| Site X Sample Date | 12 | 1.024 | 0.085 | 5.00 ** |
| Year X Site X Sample Date | 12 | 0.202 | 0.017 | |
| | 51 | 6.78 | | |

F.01 [1,12]=9.33; F.001 [12,12]=7.0; F.05 [1,12]=4.75; F.01 [12,12]=4.16

## CELL DENSITY

| Source of Variation | df | ss | ms | $F_s$ |
|---|---|---|---|---|
| Year | 1 | 9.65 | 9.65 | <1.00 NS |
| Site | 1 | 41.30 | 41.30 | <1.00 NS |
| Sample Date | 12 | 2,720 | 226.00 | 4.35 ** |
| Year X Site | 1 | 0.001 | 0.001 | <1.00 NS |
| Year X Sample Date | 12 | 261 | 21.70 | <1.00 NS |
| Site X Sample Date | 12 | 89 | 7.42 | <1.00 NS |
| Year X Site X Sample Date | 12 | 622 | 51.90 | |
| | 51 | 3,740 | | |

F.01 [12,12]=4.16

differences between years for both chlorophyll $\underline{a}$ and organic matter standing crop (Table 2.3), although the trend for peaks to occur in July and August occurred for all three years studied to date.

D.  **Annual Pattern of the Ratio of Chlorophyll a to Phaeophytin a**

The ratio of chlorophyll $\underline{a}$ to phaeophytin $\underline{a}$ was measured every 28 days as part of the analysis to index the phytoperiphyton biomass and to determine the physiological health of the algal community (APHA 1980). This ratio was found to be highly variable ranging from 1.4 to 76 for the experimental site and 0.6 to 38 for the control for the June 83 through September 84 period (last Annual Report, AE-031). This variability continued during 1985 (Table 2.4). For the 1983-1985 period, there was a tendency for the chlorophyll $\underline{a}$ to phaeophytin $\underline{a}$ values to be highest and most variable in the winter months and lowest and most stable in the summer months (Table 2.4). Because of the high degree of variability in this ratio, it is not very useful for comparing ELF effects between the experimental and control sites.

E.  **Annual Pattern of Diatom Cell Density**

Diatom cell density tended to be highly variable from one sampling period to the next (Table 2.5). In general, winter lows of 0.5 to 3.3 cells $m^{-2}$ x $10^8$ were characteristic of the experimental site (FEX, Table 2.5) while 3.0- to 6.0 cells $m^{-2}$ x $10^8$ were characteristic of the control site (FCD, Table 2.5). Summer values tended to be variable but with peaks 2-10 times greater than winter lows (Table 2.5). The tendency for FCD to have greater cell densities than FEX as reported for part of 1984 in the last annual report continued for 1985, although a reversal occurred in June and August (Table 2.5). Despite this apparent general tendency towards more cells at FCD (Table 2.5), a t-test comparison of sites in 1985 showed that there were no statistically significant differences between sites (Table 2.6). In fact, the 3-way ANOVA analysis of the 1983-1985 data demonstrated that no site differences existed for cell density estimates (Table 2.3) for the first two complete years of data. The 3-way ANOVA showed that only sample date was a significant source of variation for this paremeter (Table 2.3). Thus, site to site and year to year differences were not significant for cell density.

The cell density data did not precisely follow trends in chlorophyll $\underline{a}$ and organic matter AFDW standing crop as might have been expected. The characteristic July-August peak for the latter two was less consistent for cell density counts with peak values for density occurring in June in 1984 at FCD and in 1985 at FEX (Table 2.5 and last annual report).

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TABLE 2.4. Chlorophyll a to Phaeophytin a Ratios (Values ± SE, N in Parentheses) for the Ford River

| DATE OUT | DAYS Exposure | Control Site (FCD) | | Experimental Site (FEX) | |
|---|---|---|---|---|---|
| 10-22-84 | 28 | 4.56 ± 0.3 | (10) | 3.55 ± 0.3 | (10) |
| 11-13-84 | 28 | 5.78 ± 0.3 | (10) | 4.81 ± 0.3 | (10) |
| 12-12-84 | 29 | 20.22 ± 11.7 | (10) | 13.60 ± 2.0 | (10) |
| 1-09-85 | 28 | 14.78 ± 11.9 | (5) | 56.67 ± 41.4 | (5) |
| 2-06-85 | 28 | 5.49 ± 2.1 | (10) | | |
| 3-07-85 | 29 | 5.72 ± 0.9 | (10) | 6.95 ± 1.3 | (10) |
| 4-04-85 | 28 | 10.32 ± 2.7 | (10) | 11.92 ± 1.4 | (10) |
| 5-02-85 | 28 | 26.00 ± 12.2 | (10) | 9.71 ± 1.9 | (9) |
| 6-03-85 | 28 | 9.14 ± 1.2 | (10) | 10.24 ± 2.1 | (10) |
| 7-01-85 | 28 | 2.54 ± 1.3 | (10) | 3.13 ± 0.3 | (10) |
| 7-29-85 | 28 | 3.77 ± 0.3 | (10) | 3.29 ± 0.4 | (10) |
| 8-26-85 | 28 | 3.38 ± 0.3 | (10) | 4.33 ± 0.6 | (10) |
| 9-25-85 | 29 | 5.10 ± 0.7 | (10) | 4.10 ± 0.4 | (10) |

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The 1985 data were also converted to a biovolume basis (Fig. 2.3). When these data and the log 10 numbers·$m^{-2}$ were plotted on the same graph, a consistent pattern of insignificant differences in numbers and biovolume emerged (Figure 2.3, Table 2.6). Actually, both volumetric density and numerical density were remarkably consistent throughout the year. This trend was especially true of volumetric density since lower numbers in the winter were offset by a tendency towards fewer, but larger diatoms during this season (i.e., a switch from summertime dominance of smaller, more numerous species of Cocconeis to a winter dominance of larger, less numerous diatom species.

F.  Annual Patterns of Species Diversity and Species Evenness.

Changes in community composition may reflect the effects of a host of environmental variables, such as changing light levels, increasing or decreasing water currents, or changing water temperatures that may act individually or synergistically to subtly change the abundance of various algal species. Comparing the changes in the periphyton community through the use of a species diversity index coupled with a species evenness index can indicate subtle shifts in community structure unnoticed using other tests, such as chlorophyll a, organic biomass levels, or cell densities. Monthly changes in these two community indices (Figure 2.4A, 2.4B) indicated a close correlation of diversity and evenness for each site. The general patterns between the two sites (Figure 2.4A and B) appeared to be different with autumn peaks in the two values decreasing steadily to a low in May and early June for FCD but with an apparent spring peak at FEX. However, paired t-test comparisons between sites (Table 2.6) showed that no significant site differences existed for these parameters.

The trends of high diversity and evenness during cooler temperatures and lower diversity and evenness concomitant with warmer temperatures, lower flows and increased dominance of a few species (especially Cocconeis sp.) observed during 1985 were very similar to trends reported for 1983 and 1984 in the last annual report (AE-031).

G.  Annual Patterns of Individual Cell Volume and Total Biovolume

This year, as more individual cell measurements were completed on the dominant taxa, individual mean cell volumes were calculated for each of the twenty major diatom species. Length, width, and thickness measurements were used from the light microscope fitted with an ocular micrometer together with measurements from scanning electron micrographs, to allow calculation of morphological cell types according to the closest fitting single geometric figure or set of

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TABLE 2.5. Cell Density (No. cells·$m^{-2}$·$10^8$) and Biovolume $\mu^3$·$m^{-2}$·$10^{11}$) for Experimental (FEX) and Control (FCD) Sites for 1984-85. Means ± SE, N in parentheses.

| DATE | FEX BIOVOLUME | | FEX DENSITY | | FCD BIOVOLUME | | FCD DENSITY | |
|---|---|---|---|---|---|---|---|---|
| 10-22-84 | 0.97 ± 0.44 | (4) | 2.79 ± 0.73 | (4) | 2.41 ± 0.62 | (3) | 5.69 ± 2.31 | (3) |
| 11-13-84 | 4.15 ± 1.89 | (4) | 6.29 ± 1.82 | (5) | 7.09 ± 1.55 | (5) | 11.75 ± 3.29 | (5) |
| 12-11-84 | 1.89 ± 0.15 | (3) | 2.16 ± 0.23 | (3) | 3.53 ± 1.21 | (3) | 2.97 ± 0.83 | (3) |
| 1-09-85 | 1.49 ± 0.69 | (3) | 1.67 ± 0.54 | (3) | 5.36 ± 1.81 | (3) | 5.07 ± 0.78 | (3) |
| 2-06-85 | 0.22 ± 0.04 | (3) | 0.45 ± 0.08 | (3) | 4.95 ± 0.36 | (3) | 5.88 ± 0.10 | (3) |
| 3-07-85 | 1.42 ± 0.49 | (3) | 3.33 ± 1.16 | (3) | 3.05 ± 0.67 | (3) | 6.34 ± 1.40 | (3) |
| 4-04-85 | 0.78 ± 0.04 | (3) | 2.19 ± 0.08 | (3) | 1.93 ± 0.17 | (3) | 5.02 ± 0.25 | (3) |
| 5-02-85 | 1.77 ± 0.53 | (3) | 3.36 ± 0.93 | (3) | 3.01 ± 0.95 | (3) | 10.62 ± 0.71 | (3) |
| 6-03-85 | 4.24 ± 0.44 | (3) | 27.62 ± 2.62 | (3) | 3.30 ± 1.48 | (3) | 12.25 ± 2.48 | (3) |
| 7-01-85 | 1.37 ± 0.15 | (3) | 3.16 ± 2.11 | (3) | 1.51 ± 0.16 | (3) | 7.47 ± 0.26 | (3) |
| 7-29-85 | 3.97 ± 0.87 | (3) | 17.09 ± 3.67 | (3) | 2.26 ± 0.60 | (3) | 10.41 ± 2.04 | (3) |
| 8-26-85 | 1.81 ± 0.45 | (3) | 9.88 ± 1.35 | (3) | 3.81 ± 0.73 | (3) | 19.14 ± 4.80 | (3) |
| 9-25-85 | 3.46 ± 1.64 | (3) | 6.15 ± 2.49 | (3) | 2.33 ± 0.37 | (3) | 9.16 ± 0.48 | (3) |
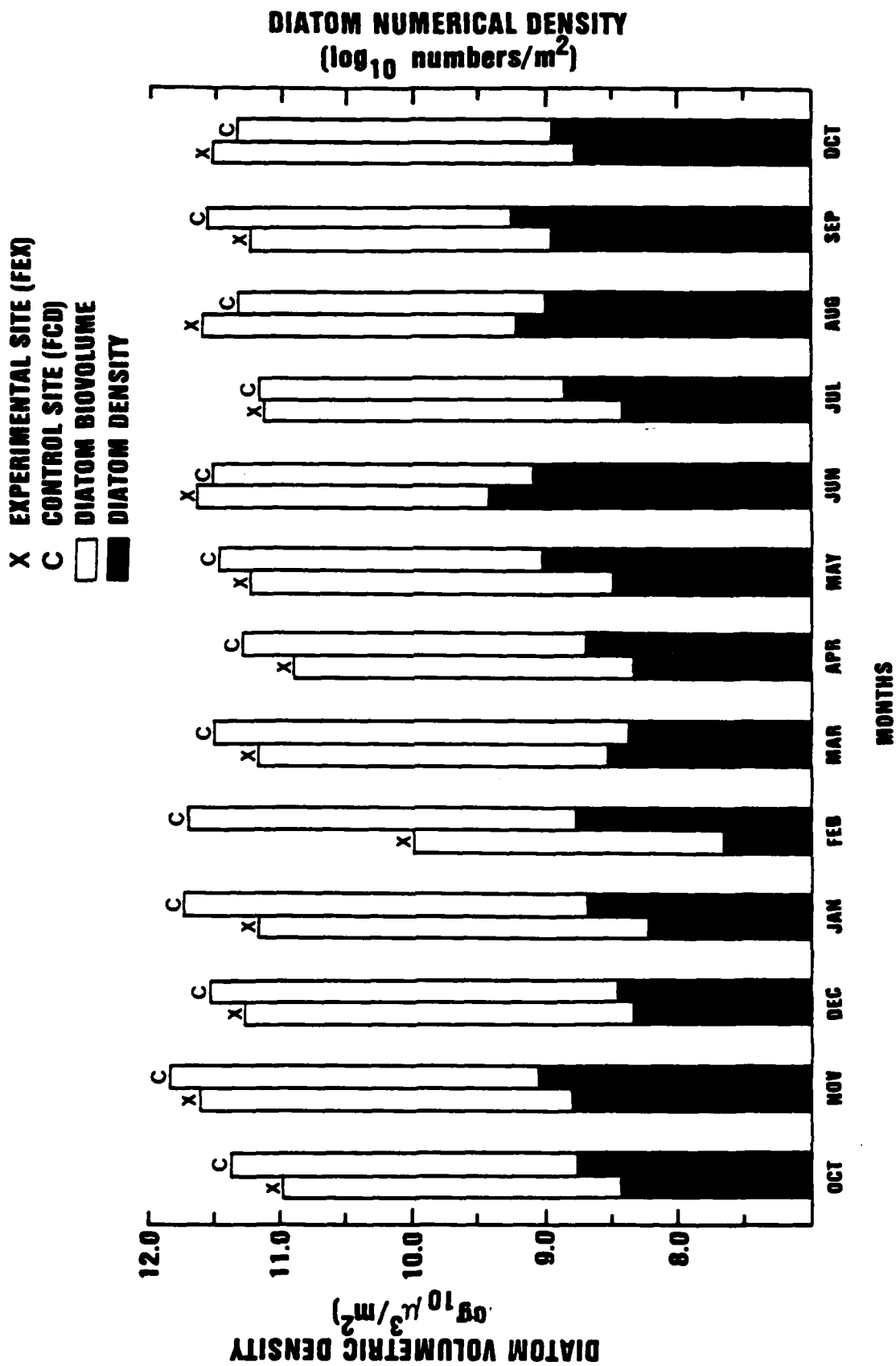
Figure 2.3. Comparison of Total Diatom Biovolume to Numerical Density

# A. EXPERIMENTAL SITE (FEX)

## SPECIES DIVERSITY AND SPECIES EVENNESS ($\bar{X}\pm$S.E.)
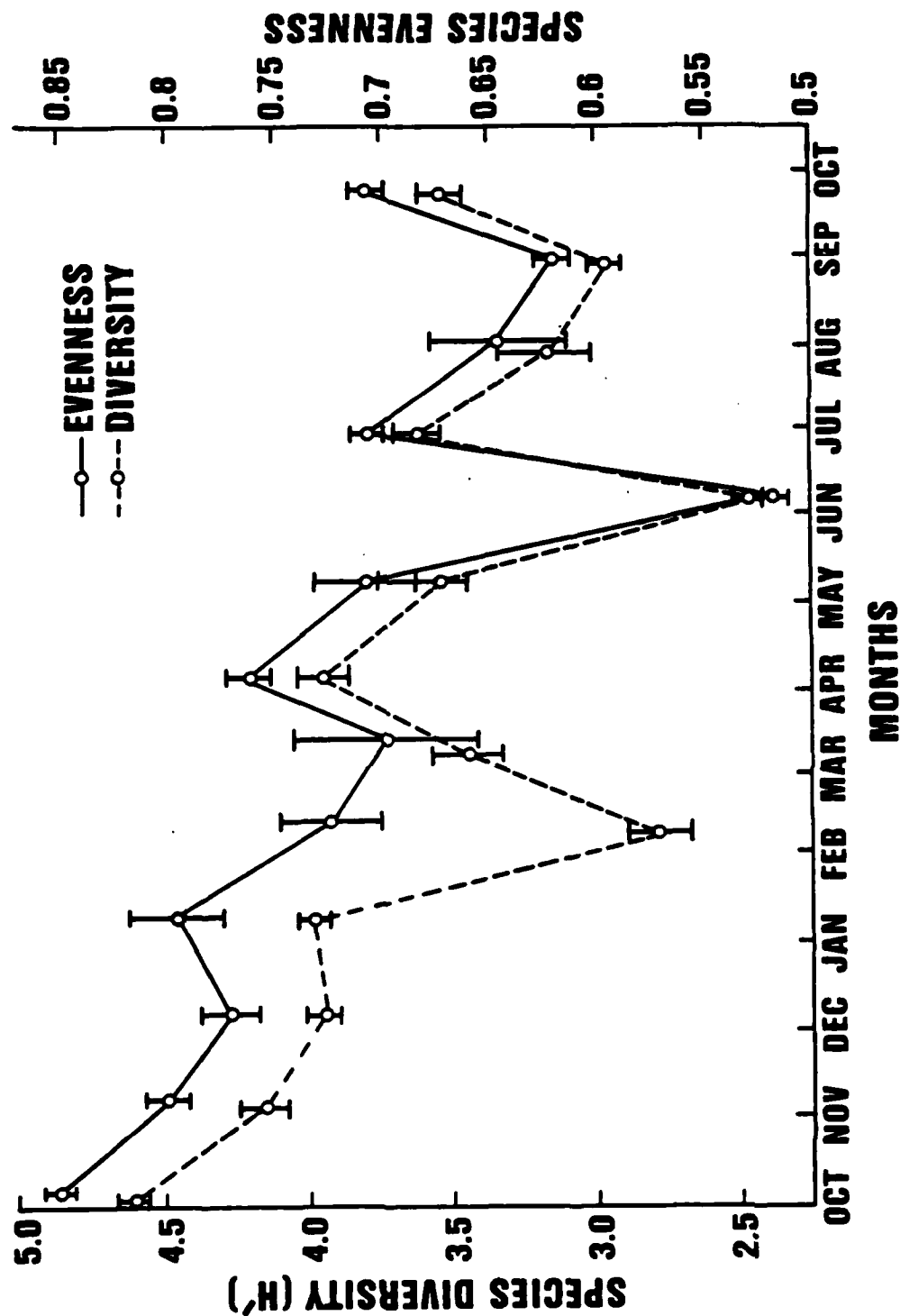


Figure 2.4. (A) Species Diversity and Species Evenness of the Diatom Community at the Experimental Site (FEX), 1984-85.

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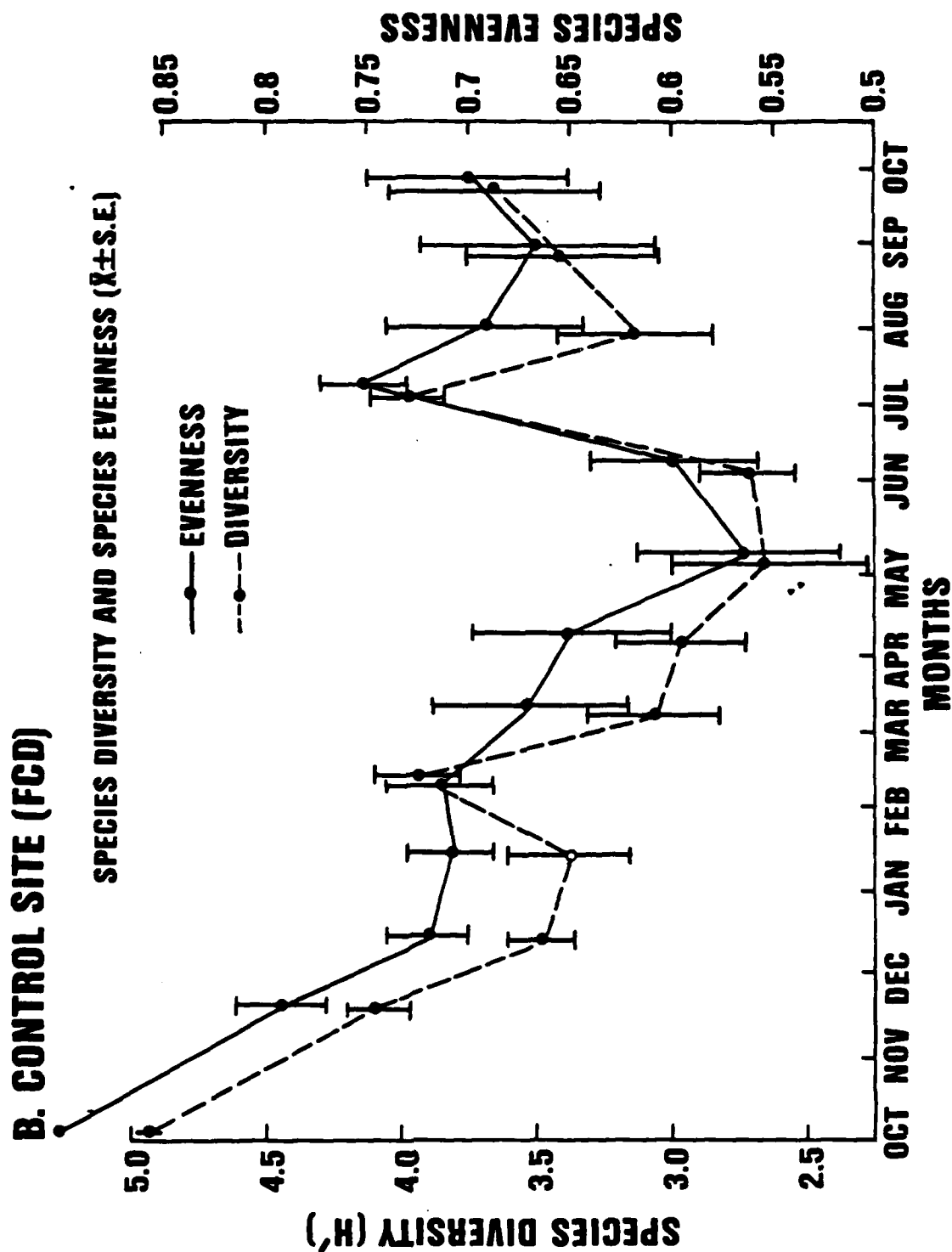
Figure 2.4. (B) Species Diversity and Species Evenness of the Diatom Community at the Control Site (FCD), 1984-85.

TABLE 2.6. Results of paired t-test Comparisons of Species Diversity ($H^1$), Species Eveness, Diatom Diversity, Cell Volume, and Biovolume between Control (FCD) and Experimental (FEX) Sites.

| TEST PARAMETER | df | Calculated t-value | Significance |
|---|---|---|---|
| Species Diversity ($H^1$) | 12 | .1740 | NS |
| Species Evenness | 12 | .6922 | NS |
| Diatom Density | 12 | 1.1086 | NS |
| Cell Volume | 12 | 1.3873 | NS |
| Biovolume | 12 | 2.4865 | *p<.05 |
| Chl a | 11 | 3.1923 | **p<.01 |
| Biomass | 12 | 0.4824 | NS |

TABLE 2.7.  Correlations Between Selected Biological Variables

| Site | Parameters | Correlation Coefficients | Sig. |
|------|-----------|--------------------------|------|
| FEX | Cell Density vs. Species Diversity | -0.5699 | NS |
| FCD | Cell Density vs. Species Diversity | -0.1851 | NS |
| FEX | Total Biovolume vs. Cell Density | 0.8633 | **(p<.01) |
| FCD | Total Biovolume vs. Cell Density | -0.0919 | NS |
| FEX | Mean Cell Volume vs. Chlorophyll $a$ | -0.4699 | NS |
| FCD | Mean Cell Volume vs. Chlorophyll $a$ | -0.4950 | NS |
| FEX | Total Biovolume vs. Chlorophyll $a$ | 0.5549 | NS |
| FCD | Total Biovolume vs. Chlorophyll $a$ | -0.1632 | NS |
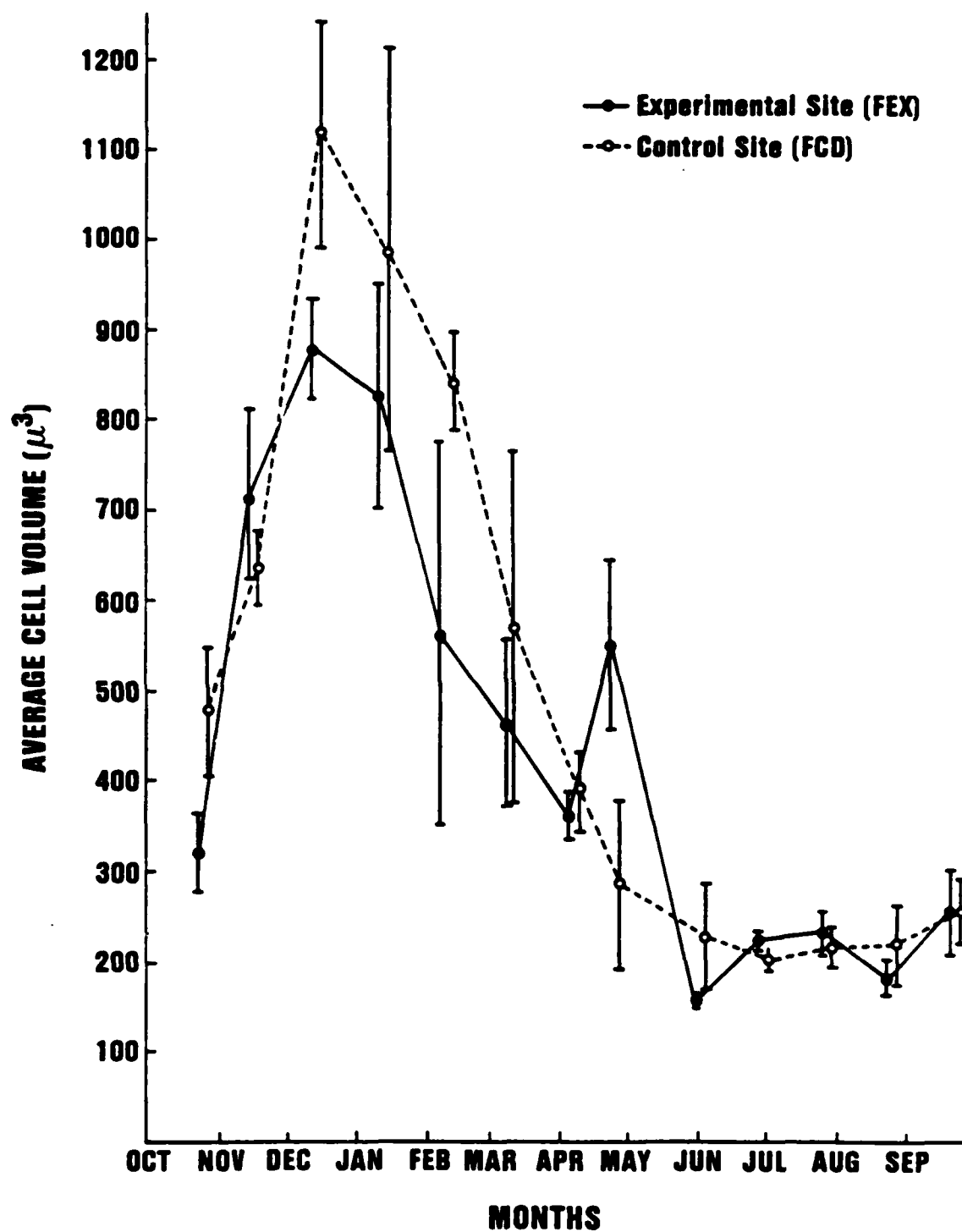
FIGURE 2.5. Average Individual Cell Volume of Diatoms from the Experimental (FEX) and Control (FCD) Sites, 1984-85.

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TABLE 2.8. Correlation Matrix for Periphyton Parameters Against Ambient Monitoring Parameters for the Ford River.

**EXPERIMENTAL SITE (FEX)**

|  | Biomass | Chl a | Cell Density | Discharge | Under Water PAR | Above Water PAR | Water Temperature | Dissolved Oxygen |
|---|---|---|---|---|---|---|---|---|
| Biomass | 1.00 | | | | | | | |
| Chlorophyll a | 0.75* | 1.00 | | | | | | |
| Cell Density | 0.53 | 0.34 | 1.00 | | | | | |
| Discharge | -0.11 | -0.30 | -0.21 | 1.00 | | | | |
| Under Water PAR | -0.20 | -0.19 | -0.26 | -0.16 | 1.00 | | | |
| Above Water PAR | -0.49 | -0.67* | -0.25 | 0.34 | 0.57* | 1.00 | | |
| Water Temperature | 0.35 | 0.58* | 0.27 | -0.91* | 0.04 | -0.49* | 1.00 | |
| Dissolved Oxygen | -0.39 | -0.59* | -0.29 | 0.86* | -0.04 | 0.44 | -0.98* | 1.00 |

*p<0.05

**CONTROL SITE (FCD)**

|  | Biomass | Chl a | Cell Density | Discharge | Under Water PAR | Above Water PAR | Water Temperature | Dissolved Oxygen |
|---|---|---|---|---|---|---|---|---|
| Biomass | 1.00 | | | | | | | |
| Chlorophyll a | 0.48* | 1.00 | | | | | | |
| Cell Density | 0.11 | 0.35 | 1.00 | | | | | |
| Discharge | -0.54* | -0.52* | -0.34 | 1.00 | | | | |
| Under Water PAR | -0.13 | -0.22 | -0.22 | -0.16 | 1.00 | | | |
| Above Water PAR | -0.49 | -0.76* | -0.18 | 0.34 | 0.57* | 1.00 | | |
| Water Temperature | 0.58* | 0.77* | 0.34 | -0.91* | 0.04 | -0.49* | 1.00 | |
| Dissolved Oxygen | -0.56* | -0.78* | -0.32 | 0.86* | -0.04 | 0.44 | -0.98* | 1.00 |

*p<0.05
critical value (2-tail, .05) = + or - .48

figures. Volume estimates were multiplied by the density of each species and summed to provide an accurate picture of total biovolume for all cells present. These biovolume results were often distinctly different from cell density measurements (Figure 2.3) and appeared to show a fairly constant value throughout the year ranging from a low of 0.22 $+$ .04 x $10^{11}$ in February for FEX (Table 2.5) to a high of $\overline{7.09} + 1.55$ x $10^{11}$ cubic microns per square meter in November at FCD. The control site showed a significantly larger (Table 2.6, p<0.05) total biovolume that did the experimental site.

Correlation coefficients calculated between selected biological variables indicated a significant relationship (r=.86, p<0.01, Table 2.7), between cell density values and total biovolumes. Given this relationship it is likely that measurement of either density or biovolume alone would be sufficient to detect ELF differences between sites. Paired t-tests did show significant differences between sites, however (Table 2.6), unlike cell density estimates.

The results of average individual cell volume calculations did, however, show a more seasonal trend (Figure 2.5) with larger cell size appearing from December-February at both sites. It may be that the larger cells assumed to be slower growing, are at less of a disadvantage when low temperatures create more equitable physiological conditions for growth between small and large cells. Thus, the large cells are not overgrown or outcompeted when rapid growth by smaller cells is not favored. Comparisons between sites again showed no significant differences in average cell volume (Table 2.6).

H. Effects of Environmental Variables on the Periphyton Community.

A series of multiple regressions were calculated for the June 1983 to June 1985 data sets for each site to examine possible relationships between environmental variables and periphyton community parameters. Due to equipment problems that occurred frequently in 1983 but were gradually solved by 1985, discharge, PAR, water temperature and dissolved oxygen data were combined to form the single best data set for these initial comparisons. The first sets of environmental variables examined were daily means from several of the automatically monitored parameters (i.e., discharge, underwater solar photosynthetically active radiation (PAR), above water solar PAR, water temperature, and dissolved oxygen). The regression of chlorophyll a at FCD with these five variables had an $R^2$ of 0.92, a multiple R of 0.96, and was highly significant (p<0.01). Deletion of dissolved oxygen from this equation essentially caused no change in this regression ($R^2$ =0.91, p<0.01). Likewise, deletion of underwater solar PAR and dissolved oxygen changed the $R^2$

only slightly ($R^2$=0.89, p<0.001). The partial $R^2$'s of
the original regression suggested that above water PAR was
the best predictor of chlorophyll a ($R^2$ = 0.60) followed by
discharge ($R^2$ = 0.28), underwater PAR ($R^2$ = 0.17), and
dissolved oxygen ($R^2$ = 0.15). Temperature had little
additional predictive value. A correlation matrix was also
calculated for these parameters (Table 2.8). It suggested
that the strongest positive correlation was between water
temperature and chlorophyll a and that above water PAR had an
even stronger negative correlation with chlorophyll a for
both sites. Both above water PAR and dissolved oxygen were
significantly negatively correlated with temperature during
the growing season when these ambient parameter were
monitored in detail (Table 2.8). These correlations led us
to suspect that temperature might be the driving variable,
especially since above water PAR was negatively correlated
with chlorophyll a (the reverse of what we expected since PAR
should be one of the positive driving variables for
chlorophyll production). Thus, a regression of just
temperature and chlorophyll a was calculated. At FCD,
temperature alone was a slightly better predictor of
chlorophyll a ($R^2$ = 0.59, R = 0.77, p< 0.01) than was above
water PAR alone ($R^2$ = 0.58, R = -0.76, p<0.01). At FEX,
these regressions were less robust (R = 0.58 for temperature
versus chlorophyll a, p<0.1 for the regression but p< 0.05
for the correlation matrix, Table 2.8; R = -0.67 for above
water PAR, p < 0.05). From these analyses we concluded that:
(1) multiple regressions of discharge, above water PAR,
underwater PAR, temperature, and dissolved oxygen were
excellent predictors of chlorophyll a at both sites; (2)
little predictive power was lost from deletion of underwater
PAR and dissolved oxygen from these regressions ($R^2$ for
remaining three variables was 0.89 at FCD, p < 0.001 and 0.74
for FEX p < 0.05); (3) above water PAR alone was the best
predictor of chlorophyll a; it was negatively correlated at
both sites ($R^2$ = 0.58, p < 0.01 at FCD; $R^2$ = 0.46, p <
0.05 at FEX; and (4) water temperature alone was almost as
good a predictor of chlorophyll a  as was above water PAR
(positively correlated R = 0.77 at FCD, p < 0.01; R = 0.58, p
< 0.1 at FEX).

The same types of multiple regression analyses of
organic matter biomass (AFDW) and ambient monitoring
parameters resulted in no significant regression equations
for either site. Likewise, multiple regressions of cell
density against ambient monitoring parameters resulted in no
significant relationships at either site. The correlation
matrices for these two sites (Table 2.8) suggested that
biomass was significantly positively correlated with
chlorophyll a and negatively correlated with above water PAR.
No other significant correlation held for both sites (Table
2.8). Diatom cell density was correlated with biomass at FEX
but not at FCD and no other significant correlation existed
with any ambient monitoring or biological parameter (Table

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2.8).

A second series of multiple regressions were calculated
for each of the biological parameters (chlorophyll a,
biomass, density) against selected nutrients. Organic
nitrogen, total phosphorus and silica were included in the
first set of regressions. The $R^2$ for chlorophyll a against
these parameters was 0.53 at FEX ($p < 0.05$) and 0.36 at FCD
($p < 0.10$). Total P had the largest partial $R^2$ at both
sites with Si contributing very little to the multiple R.
The multiple regressions were not significant for organic N,
total P and Si for either organic matter biomass or cell
density. Regressions of inorganic N plus organic N against
the three biological parameters were not significant for
chlorophyll a or biomass at either site, but was significant
for cell density at FCD ($R^2 = 0.46$, multiple R = 0.68, $p <$
0.05) but not at FEX. Regressions of ammonium N, nitrate N,
nitrite N, and organic N against the biological parameters
resulted in significant $R^2$ values only for density and
chlorophyll a at FCD (not at FEX).

Correlation matrices for nutrients and the three
biological parameters were also calculated. No significant
correlation between any biological parameter and any chemical
constituent existed for both sites with the exception of
total P and chlorophyll a and density. However, total P was
positively correlated with these two parameters at FEX and
negatively correlated at FCD. This reversal plus low R
values (0.48 to 0.56) suggested that these correlations meant
very little.

Correlation matrices were also calculated for field
chemistry data (pH, alkalinity, hardness, conductivity and
dissolved oxygen) and the three biological parameters.
Again, no significant correlation existed for both sites for
any biological parameter and any chemical constituent. For
both this field chemistry data and the nutrient data, there
were several significant correlations between biomass and
chemical constituents and between chlorophyll a and chemical
constituents at FCD that were not significant at FEX. Even
though the values were significant at FCD, they were low (R
values ranged from +/-0.42 to 0.61). These low R values and
lack of intersite consistency suggested that these
correlations were not very meaningful.

I.  Photosynthesis – respiration ratio studies (P/R)

A separate study was undertaken to evaluate primary
production using short term changes in dissolved oxygen gas
concentrations during the summer period of intense algal
growth. The dissolved gas procedures are advantageous
because estimates of community primary productivity, gross
productivity, and community respiration may be obtained with
one technique (Bott et al. 1978). Rocks from the stream bed

TABLE 2.9   HOURLY PRODUCTION AND RESPIRATION RATES
FOR ROCK SUBSTRATES OF THE FORD RIVER

| DATE | NET PRIMARY PRODUCTION | | RESPIRATION * | | GROSS PRIMARY PRODUCTION ** | |
|---|---|---|---|---|---|---|
| | mg $O_2$/mg chl a/m² | mg $O_2$/m² | mg $O_2$/mg chl a/m² | mg $O_2$/m² | mg $O_2$/mg chl a/m² | mg $O_2$/m² |
| | | | FORD CONTROL SITE (FCD) | | | |
| 6/25/85 | 5.8 + 1.4 | 118 + 15 | 2.4 + 0.8 | 55 + 11 | 7.6 | 173 |
| 7/2/85 | 3.8 + 0.4 | 138 + 10 | 1.5 + 0.2 | 58 + 15 | 5.3 | 196 |
| 7/10/85 | 3.0 + 1.4 | 96 + 50 | 0.5 + 0.4 | 10 + 9 | 4.0 | 106 |
| 7/23/85 | 6.9 + 4.9 | 92 + 19 | 1.50 + 0.5 | 23 + 7 | 7.0 | 115 |
| 7/30/85 | 7.2 + 2.7 | 83 + 13 | 4.4 + 4.7 | 61 + 53 | 10.0 | 144 |
| 8/8/85 | 6.5 + 2.2 | 105 + 19 | 1.7 + 0.4 | 27 + 9 | 7.7 | 132 |
| 8/14/85 | 6.7 + 2.5 | 109 + 14 | 2.5 + 0.6 | 28 + 1 | 9.1 | 137 |
| x̄ + S.D. | 5.7 + 1.6 | 106 + 18 | 2.1 + 1.2 | 37 + 20 | 7.2 + 2.0 | 143 + 32 |
| | | | FORD EXPERIMENTAL SITE (FEX) | | | |
| 6/25/85 | 6.0 + 2.8 | 63 + 13 | 3.2 + 0.9 | 24 + 10 | 9.6 | 87 |
| 7/2/85 | 5.2 + 0.6 | 134 + 28 | 1.8 + 0.3 | 6 + 5 | 6.5 | 190 |
| 7/10/85 | 6.0 + 1.3 | 80 + 8 | 1.3 + 0.6 | 23 + 5 | 5.8 | 103 |
| 7/23/85 | 6.3 + 1.0 | 114 + 14 | 2.3 + 0.5 | 47 + 2 | 8.1 | 160 |
| 8/1/85 | 7.6 + 0.2 | 102 + 28 | 4.6 + 1.6 | 63 + 4 | 11.5 | 165 |
| 8/8/85 | 7.1 + 0.9 | 111 + 18 | 1.9 + 1.1 | 35 + 12 | 8.1 | 146 |
| 8/14/85 | 6.8 + 0.4 | 115 + 11 | 1.4 + 0.9 | 29 + 9 | 7.4 | 144 |
| x̄ + S.D. | 6.4 + 0.8 | 103 + 24 | 2.4 + 1.2 | 39 + 15 | 8.1 + 1.9 | 142 + 36 |

* = Gross Respiration of Entire Microbial Community (Bacteria and Algae)

**= Total Metabolism = Respiration + Net Primary Production.

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were placed inside each of six plexiglass chambers occupying 1/3 to 1/4 of the total chamber volume (3-4 l). Three light and three dark chambers were run simultaneously on each date. Recirculated water was continuously recycled through submersible pumps. Each test lasted from 0.5-2.0 hours between 1000-1300 hours of each test day in 1984. One site was tested during one week, and the second was tested during the following week in 1984. Even though 1984 results indicated no significant difference (t-test) between sites for net production, respiration, or gross production, the relatively large standard deviations led us to change procedures somewhat for 1985. During 1985, both FCD and FEX were tested on the same day with the test at each site lasting one hour. Tests were begun at one site at 1000 hours a..d were completed at the other site by 1400 hours. Alternate sites were tested first in alternate weeks.

The assumptions made for the purposes of production calculations considered algal periphyton to occupy only the upper surface half of each rock. Surface area was therefore determined by wrapping each rock in aluminum foil, straightening the foil, and determining the area using a leaf area meter (LI-COR). Production estimates per mg of chlorophyll a per meter square of rock surface were also calculated after subjecting the rocks with attached periphyton to chlorophyll a extraction.

Gross and net primary production and respiration were very similar between the control (FCD) and experimental (FEX) sites in 1985 (Table 2.9). As had been true in 1984, there were no significant differences (paired t-tests) between sites for any of the parameters in 1985. The modified procedures used in 1985 resulted in lower standard deviations for each parameter and in additional convergence of mean values between sites (Table 2.9 and last annual report, AE-031). Differences between years were not very great for these parameters suggesting that this community based comparison will offer a robust means for detection of possible ELF effects once the antenna goes operational.

Since chlorophyll a was determined for the rock substrates in each chamber for these production/respiration studies, data were available for comparison of 28 day glass slide standing crop with standing crop on rock surfaces. This comparison (Table 2.10) showed that chlorophyll a per square meter of rock surface was fairly constant from late June through mid-August while glass slide standing crop rose from a low on July 2 to yearly peak values on July 30. Glass slide standing crop was significantly lower than rock substrate standing crop on the two dates with comparable data (Table 2.10). This disparity was especially large on July 2. During the June 25-August 14 period where rock substrate data were available, discharge varied only from 0.3 to 1.3 $m^{-3}$ sec $^{-1}$ (Fig. 1.3). Average daily temperature increased

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TABLE 2.10.  A Comparison of Chlorophyll a from Rock Substrates with Chlorophyll a from Glass Slides.  Values are $mg \cdot m^{-2}$ + One Std. Dev., N in Parentheses

| DATE OUT | CONTROL SITE (FCD) | | EXPERIMENTAL SITE (PEX) | |
| | ROCKS | 28 d Glass Slides | ROCKS | 28 d Glass Slides |
| --- | --- | --- | --- | --- |
| 6-25-85 | 22.76 + 5.07 (6) | | 9.12 + 3.20 (5) | |
| 7-2-85* | 37.34 + 3.69 (6) | 1.65 + 0.33 (10) | 29.18 + 7.51 (6) | 0.67 + 0.21 (10) |
| 7-10-85 | 26.41 + 5.88 (5) | | 17.73 + 6.90 (5) | |
| 7-23-85 | 16.40 + 6.52 (6) | | 19.88 + 5.12 (6) | |
| 7-30-85* | 14.37 + 4.39 (6) | 7.43 + 1.72 (10) | 14.34 + 4.75 (6) | 9.23 + 1.65 (10) |
| 8-8-85 | 17.14 + 6.65 (6) | | 17.95 + 4.65 (6) | |
| 8-14-84 | 15.11 + 7.18 (6) | | 19.40 + 6.78 (6) | |
| Mean per Date | 21.36 + 8.30 (7) | 4.54 + 4.09 (2) | 18.22 + 6.09 (7) | 4.95 + 6.05 (10) |

from 14°C in late June to more than 18°C in August (Fig. 1.1). The most significant positive correlation between chlorophyll a on glass slides and ambient parameters was between chlorophyll a and temperature (Table 2.8). Discharge was not significantly correlated with chlorophyll a on glass slides for FEX but was for FCD. We also showed in our studies of colonization (last annual report, AE-031) that rate of colonization was slower during cooler temperatures. Once a "mature" community is established on rocks, it appears to persist at a fairly constant level from late June through August (Table 2.10). However, glass slide data appear to be much more influenced by fluctuations in ambient conditions, especially temperature and solar radiation (Table 2.10), resulting in variability from one sampling date to the next, perhaps related to colonization dynamics. Thus, the chlorophyll a data resulting from these P/R studies may offer a more stable means of comparison of ELF effects than does the 28 day glass slide data. For the next year, both types of data will be collected for corroboration of this possibility.

J. Summary

### 1. Chlorophyll a

Annual patterns for chlorophyll a standing crop and accrual were characterized by considerable year-to-year variability. The only consistency between data for 1985 and data for the two previous summers was a July-August peak. This peak varied in magnitude between years but always occurred. In 1985, no site differences were detected ($p < 0.05$) between FCD and FEX for chlorophyll a. Differences had occurred in 1983 and 1984. This lack of intersite difference in 1985 coupled with use of 3-way ANOVA analyses suggest that this parameter can be used to detect differences which may occur between sites once ELF exposure begins.

### 2. Organic Matter

Organic matter standing crop and accrual rates showed considerable year to year variability as had chlorophyll a. These parameters have consistently been characterized by no significant differences between sites since the start of the project in 1983. this trend continued in 1985. the only year to year consistency has been a July-August peak in standing crop and accrual rates.

### 3. Chlorophyll a to Phaeophytin a Ratios

This ratio continued to vary widely throughout the year in 1985. It is not a useful parameter for detection of ELF effects.

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### 4. ᴆ atom Cell Density

Diatom cell density continued to be characterized by no
statistical differences between sites ($p < 0.05$). Trends in
cell density do not include a July-August peak. Instead,
individual numbers tend to be high throughout the summer with
some tendency towards a June peak. Conversely, individual
cell volume tends to be higher in the winter.

### 5. Species Diversity and Evenness

Diatom species diversity and evenness was not
significantly different between FEX and FCD in 1985
continuing the trends established in 1983 and 1984. Annual
trends continued to be characterized by high diversity and
evenness during winter with lower values during the summer.

### 6. Total Biovolume and Individual Cell Volume Studies

Individual cell volume of the 20 dominant diatom species
were not significantly different between the experimental and
control sites. Total viobolume was significantly larger at
the control site than at the experimental site.

### 7. Correlation with Environmental Variables

Multiple regression analyses and correlation matrices
suggested that chlorophyll a standing crop was correlated
with (1) above water solar radioation, discharge, and water
temperature and (2) totao P, organic N, and dissolved silica.
However, neither diatom cell density nor organic matter
standing crop were correlated with these parameters. No
single parameter or set of environmental parameters were
capable of predicting all three of the major biological
parameters (cell density, chlorophyll a and organic matter
standing crops or accrual).

### 8. Photosynthesis-Respiration Studies

Net production, respiration, and gross production of the
community on rock surfaces did not differ significantly
between FEX and FCD in either 1984 or 1985. These
measurements appear to offer a precise means of detecting ELF
effects on community metabolism. Comparison of chlorophyll a
data from rock surfaces compared to glass slide data
suggested that the rock surface data offered a more precise
means of intersite comparison.

## J. References

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## Element 3 - Effects of Exposure Period on Insect Colonization of Artificial Substrates

Changes from the Original Synopsis - None.

### Objectives

1)To determine optimum insect colonization period for substrates, and 2) to determine insect colonization patterns onto substrates over time.

Element 3 has been deleted, as prior data for this element showed that 28 to 30 days' incubation of substrates was sufficient for optimum insect colonization (See 1983 Annual Report). These data were used to determine incubation periods for Element 4.

## Element 4 - Species Richness and Biomass of Stream Insects from Artificial Substrates in Riffles

Changes from the Original Synopsis - None.

### Objectives

1) To monitor structural community parameters for benthic insect fauna over time at FEX and FCD sites; 2) to monitor functional community parameters over time at FEX and FCD sites; 3) to monitor changes in size classes of selected insects over time at FEX and FCD, and 4) to compare 1983 - 1984 data with 1984 - 1985 data.

Extremely low frequency waves may alter structural and functional community parameters as well as life histories of the benthic fauna. The phenomenon that may be most sensitive to ELF influence could be life history patterns. As all species cannot be monitored, we chose species that fit the following criteria: 1) Found in large numbers (reducing problems of variance); 2) have discrete generation times (enabling tracking of growth phenomena); and 3) are members of functional feeding groups that may respond faster to ELF effects on food resources such as periphyton levels (grazers, collector-gatherers).

### Materials and Methods

The 60 μm mesh-lined 18 x 28 x 10 cm substrate sample baskets used for the 1983 - 1984 seasons were used, and samplers were placed in the same locations as before. From June through September of 1984, five replicates from FEX and five replicates from FCD were collected at monthly intervals, with sampler replacement after each collection. In September of 1984, 35 samplers were placed in substrates at each site for seven collection periods of five replicates each per site. After May, 1985, five samplers were placed in each of the two sites each month after that month's samples were collected until September of 1985. At that time, 35 more samplers for the fall and winter collections were placed at each site.

Samples were processed by placing samplers in individual buckets, washing sediments thoroughly and re-taining the suspended animals in a 60 μm mesh soil sieve. Animals were preserved in 80% ethyl alcohol. The sediments were replaced in the sampler and then the sampler was replaced in the stream for May through September samples. In September, fresh substrates were used for the fall and winter collections. In the laboratory, insects were picked from detritus and then separated to order level. Individuals were identified to the lowest taxon possible and then were measured to the nearest mm. for biomass estimates

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(after Smock, 1980 in cases where we had not directly determined the regression). Numbers of individuals, taxon diversity (H'), taxon richness (S), evenness (J') and perecent numerical dominance for selected species were determined for each replicate. Total sample biomass, biomass for functional feeding groups (after Merritt and Cummins, 1984) and mean dry weight per individual (DW/IND) values were computed. Statistical analyses included power tests, coefficient of variation values, Student-t tests for differences between means, 2-Way ANOVA tests for differences between sites over time for H', S, J', and percent dominance of chironomids. DW/IND values were computed for insects that had high numerical abundances. Those were: Chironomidae, Paraleptophlebia mollis, Ephemerella invaria,, E. subvaria, Optioservus sp., and Tipula spp. Additional species with high numerical abundances were also analyzed, but changes in size classes over time were random; as no clear pattern emerged, those data are not presented. They included: Baetis macdunnoughi, Ophiogomphus colubrinus, and Atherix variegata.

## Overall Philosophy Regarding Power Analysis and Environmental Testing

The issue of sample size and power analysis is very complex. The sample variances have several components. Some of the sums of squared deviations are due to sample methodology, some are due to fluctuations in environmental conditions (light levels, flow rates, water temperatures), and some are biological (growth stage). All of these varied effects may change rapidly and dramatically between seasons, months, and even several days' sample collections. This is further complicated when one compares two sites that are not exactly equal, given the fact that we are dealing with a unidirectional (a river) system. The selection of sample size is a trade-off between precision, number of community parameters sampled, and budgetary limitations. Since there are few existing hypotheses identifying specific processes that are affected by ELF fields, the decision was made to include a variety of ecological processes. We have chosen a variety of parameters for robustness rather than focusing on detection of subtle effects on one or two ecological processes. The risk of not including an adequate array is more important than missing subtle shifts with only a few processes requiring large investments of sample analyses. This position is ecologically and socially justified.

The data gathered before the antenna becomes operational represent the baseline pattern of seasonal and annual variation. These data will then be contrasted with patterns observed at the control site after the antenna is functioning. One is not going to be testing ecological differences on a short-term single point basis. The

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important ecological patterns are the temporal patterns
occurring between seasons and between years.

## Results and Discussion
### 1984 - 1985 Data

1. Structural Community Indices.-- Taxon diversity
(H') was lower in the winter months (November through
February) than at other times of the year (Fig. 4.1). H'
was significantly higher at FEX than at FCD. Temporal changes
for H' between the two sites were significantly different as
shown by a 2x11 2-Way ANOVA (Table 4.1, note interaction
term).

TABLE 4.1
Diversity (H') of Insects in Substrates at FEX and FCD
over Time (2-Way ANOVA)

| Source | d.f. | MSS | F-ratio | Prob. |
|---|---|---|---|---|
| Site | 1 | 0.746 | 9.688 | .002*** |
| Months | 10 | 2.871 | 37.494 | .0001*** |
| Interaction | 10 | 0.636 | 8.260 | .0001*** |
| Error | 88 | 0.077 | | |

Coefficient of variation (C.V.) values within
replicates ranged from 5% to 22% with a mean of 15%.

Taxon richness (S) values were also significantly
higher at FEX than at FCD Fig. 4.1). Temporal changes of S
over time between the two sites were not significantly
different when July of 1984 data were excluded (the greatest
deviation), as shown by a 2x10 2-Way ANOVA (Table 4.2, see
interaction term).

TABLE 4.2
Taxon Species Richness (S) on Insects in Substrates at FEX
and FCD over Time (2-Way ANOVA)

| Source | d.f. | MSS | F-ratio | Prob. |
|---|---|---|---|---|
| Site | 1 | 123.210 | 12.091 | .0008*** |
| Months | 9 | 260.121 | 25.527 | .0001*** |
| Interaction | 9 | 19.366 | 1.900 | .064 |
| Error | 80 | 10.190 | | |

C.V. values within replicates ranged from 8% to 26%
with a mean of 18%.

**DIVERSITY, FEX and FCD**



MONTHS: July 1984 - July 1985
□FEX, H' △FCD, H'

**TAXON RICHNESS, FEX AND FCD**



MONTHS, July 1984 - July 1985
□FEX △FCD
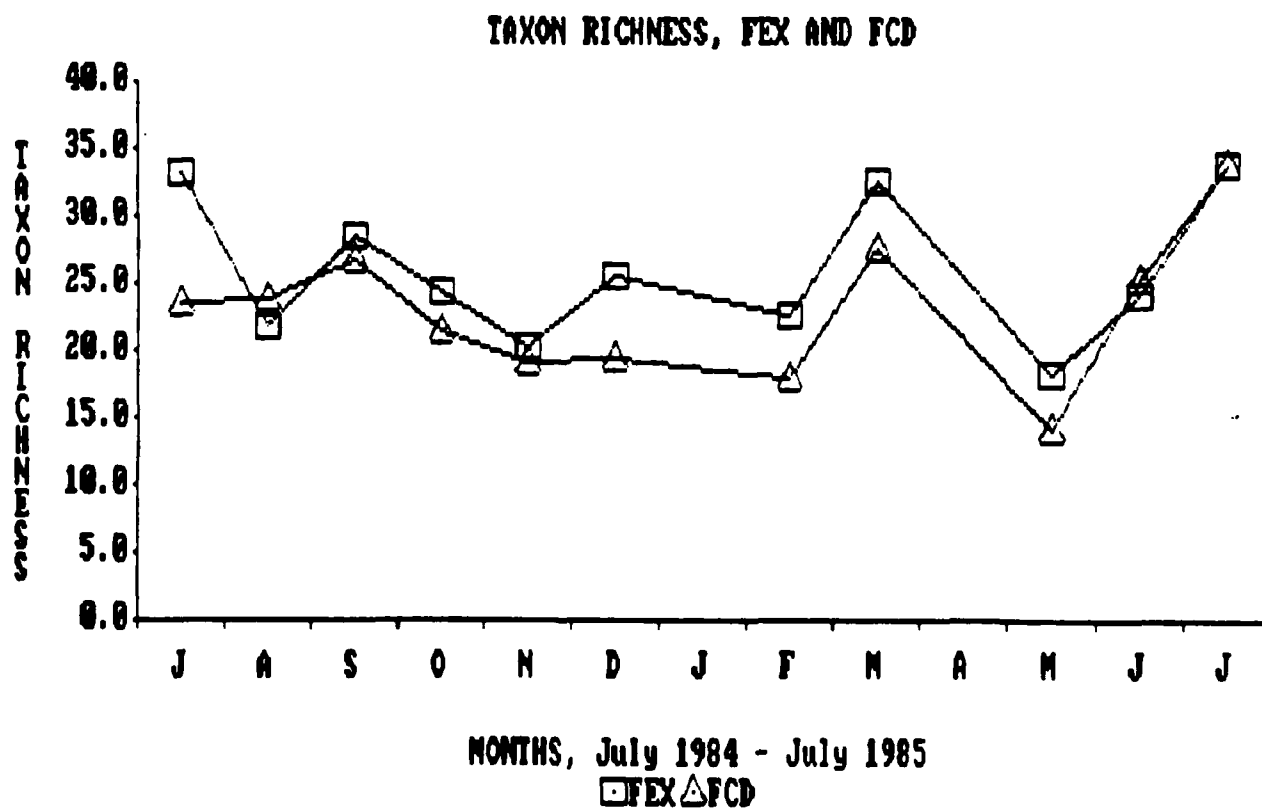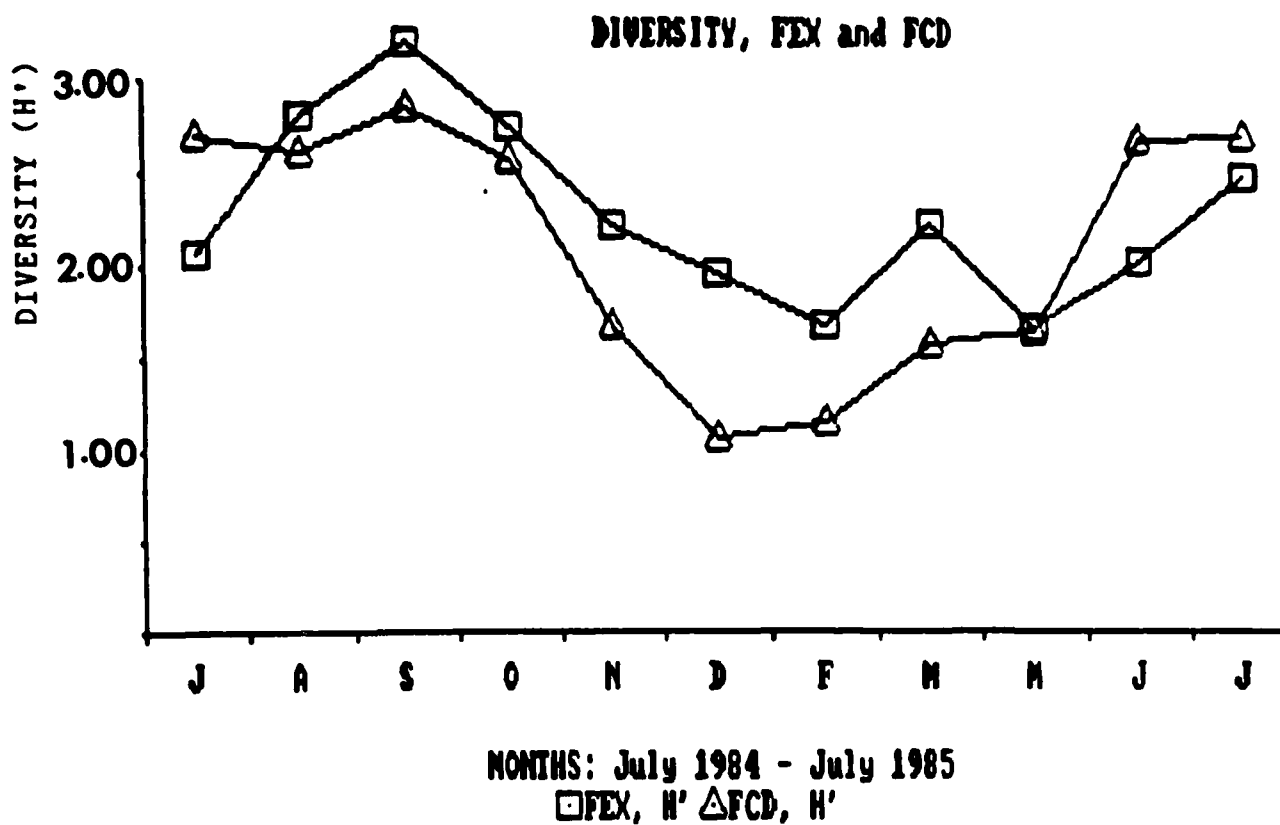
FIGURE 4.1   Diversity (H') and taxon richness (S) at FEX and
FCD, July 1984 through July, 1985.

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Evenness (J') values between FEX and FCD were not
significantly different (See Fig.4.2). Temporal changes
within each site and between sites were significantly
different (Table 4.3).

TABLE 4.3
Evenness (J') for insects in substrates at FEX and FCD
over Time (2-Way ANOVA)

| Source | d.f. | MSS | F-ratio | Prob. |
|---|---|---|---|---|
| Site | 1 | .010 | 3.460 | .0579 |
| Months | 10 | .109 | 37.716 | .0001*** |
| Interaction | 10 | .031 | 10.726 | .0001*** |
| Error | 88 | .00289 | | |

C.V. values from month to month for J' ranged from 5%
to 17% with a mean of 12%.

There was a higher correlation between J' and H' than
between J' and S, indicating that the benthic community was
not in equilibrium over time (Table 4.4a, also figs. 4.1,
4.2) See Tramer, 1969, for discussion of equilibrium versus
non-equilibrium communities.

TABLE 4.4a
Correlation Matrix for Structural Community Parameters.
Insects in Substrates from July, 1984 through July, 1985

| | FEX S | FCD S | FEX H' | FCD H' | FEX J' | FCD J' | FEX %Chiro | FCD %Chir* |
|---|---|---|---|---|---|---|---|---|
| FEX,S | 1.00 | | | | | | | |
| FCD,S | .80 | 1.00 | | | | | | |
| FEX,H' | .26 | .55 | 1.00 | | | | | |
| FCD,H' | .35 | .59 | .69 | 1.00 | | | | |
| FEX,J' | -.03 | .34 | .95 | .61 | 1.00 | | | |
| FCD,J' | .21 | .43 | .63 | .98 | .59 | 1.00 | | |
| FEX, %Chironomids | | | -.68 | -.76 | -.70 | -.75 | 1.00 | |
| FCD, %Chironomids | | | -.62 | -.98 | -.58 | -.98 | .81 | 1.00 |

* Percent numerical dominance of Chironomidae relative to
total numbers of all individuals.
================================================================
TABLE 4.4b
Correlation Matrix for Numbers of Individuals (including
chironomids) and for Numbers of Chironomids from July, 1984
Through July, 1985

| | FEX No. Ind. | FCD No. Ind. | FEX No. Chiro. | FCD No. Chiro. |
|---|---|---|---|---|
| FEX,No.Ind. | 1.00 | | | |
| FCD,No.Ind. | .38 | 1.00 | | |
| FEX,No.Chiro. | .89 | .51 | 1.00 | |
| FCD,No.Chiro. | -.06 | .81 | .22 | 1.00 |

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# EVENNESS, FEX and FCD



MONTHS: July 1984 - July 1985
□FEX, J' △FCD, J'

# CHIRONOMIDAE, FEX AND FCD



MONTHS: July 1984 - July 1985
■FEX,%CHIRO □FCD,%CHIRO
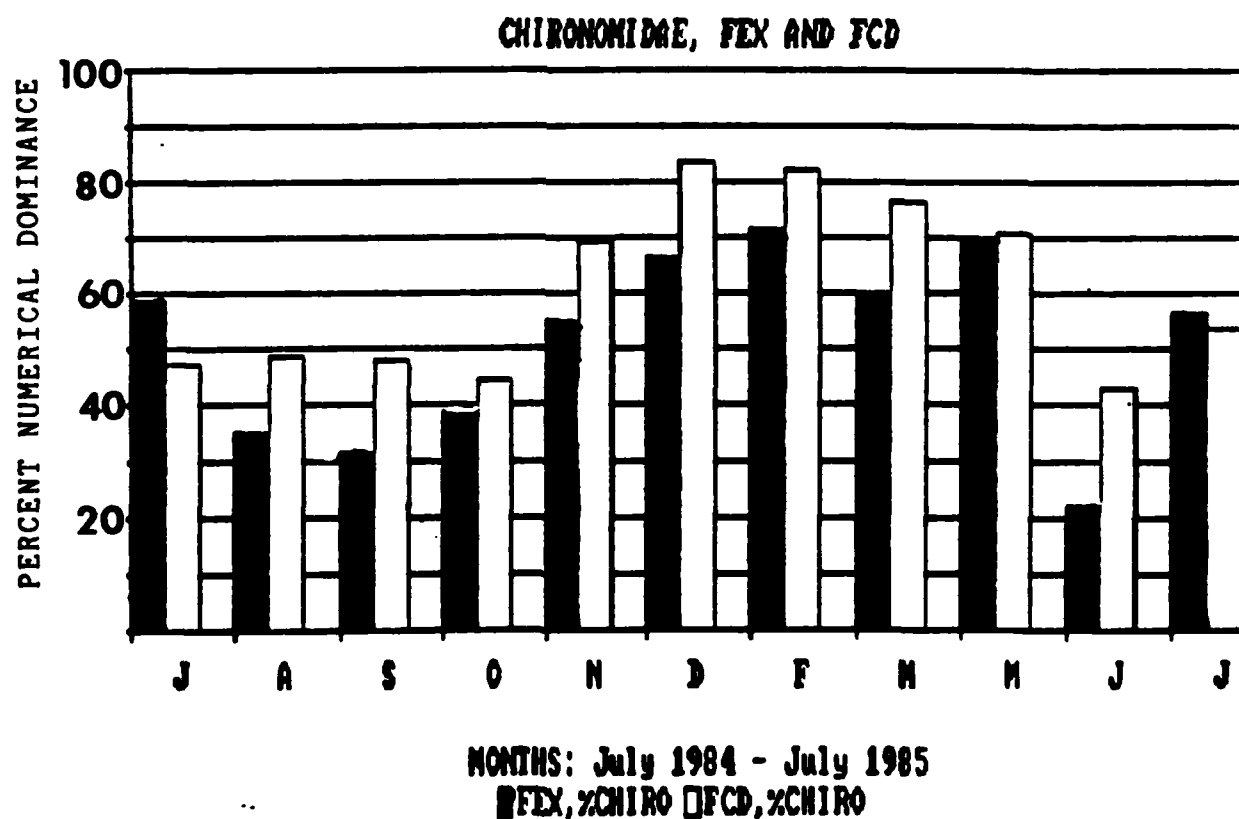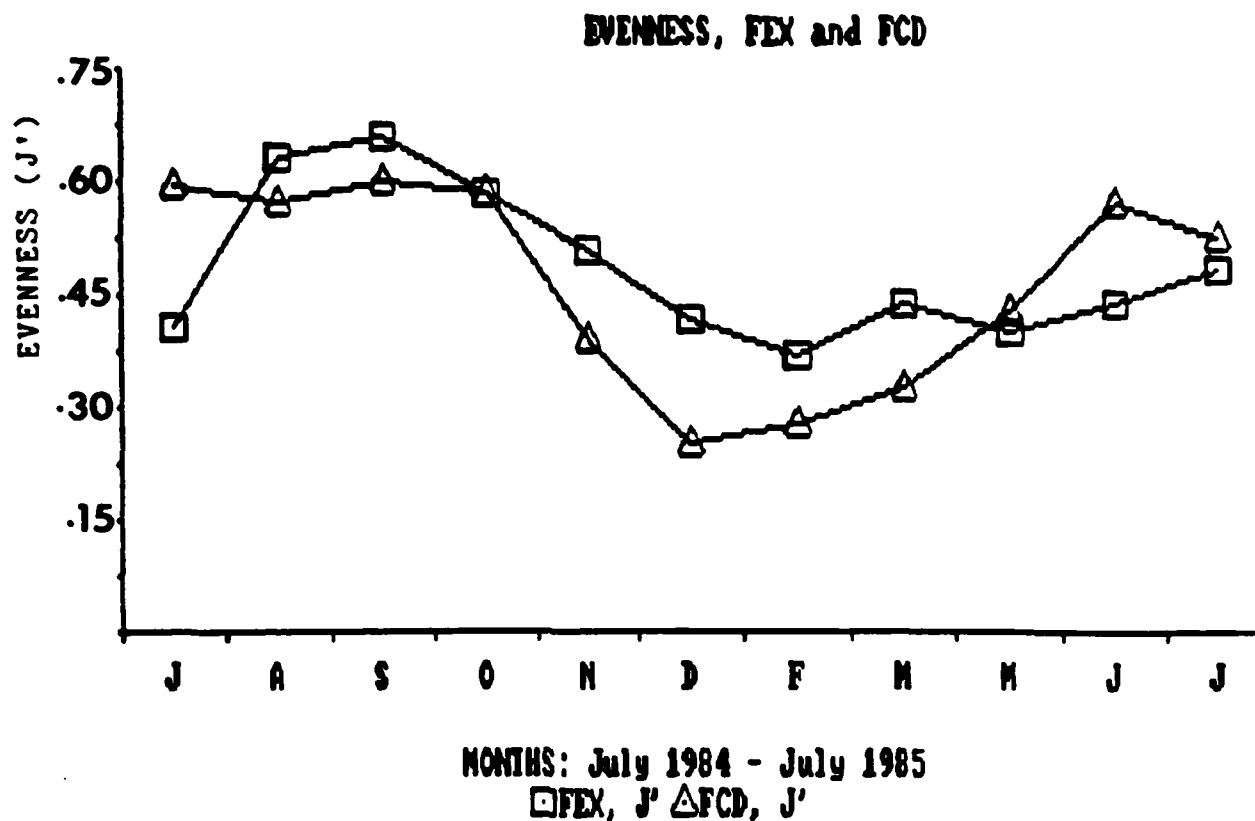
FIGURE 4.2  Evenness (J') and percent numerical dominance of the Chironomidae at FEX and FCD, July, 1984 through July, 1985.

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J' and H' are correlated inversely with respect to numerical dominance of the family Chironomidae (Table 4.4a). When J' and H' go down during the winter months, percent dominance of chironomids increases (Fig. 4.2). Because chironomids strongly biased values of J' and H', we will exclude the family prior to running J' and H'to determine those parameters with and without chironomids. Numbers of chironomids are also correlated with numbers of individuals (Fig 4.3, Table 4.4b).

2. Functional Community Indices.-- Over 50% of the total insect biomass at FEX spanned only three months (July through September, 1984); whereas, for that same time period only 27% of the total biomass accrued at FCD (Fig. 4.4). The lowest biomass values for a three-month period was from November, 1984 through February, 1985. During that time 12% of the total biomass had accumulated at FEX and 24% had accumulated at FCD. From March through July of 1985, 28% had accrued at FEX, but 47% had accrued at FCD. Thus, total biomass values, broken down as cumulative percent for each sample month were dissimilar between sites. Cumulative percent for biomass values, however were similar to cumulative percent numerical abundances (compare Fig. 4.4 with Fig. 4.5). Numerical abundances and biomass values are "coarse-grained" parameters with high C.V. values (high variance). A more "fine-grained" analysis was done -- an analysis of temporal changes in mean dry weight per individual values (DW/IND) for insects that met the following criteria: 1) high numerical abundance at both sites, 2) univoltine life history (minimizing problems with overlapping generations), and 3) the sum of taxa chosen being members of differing functional feeding groups, if possible. Life cycle patterns, inferred from mean size class changes for each taxa, are described below

a. Chironomidae. The high numbers of individuals (often 500 to 1000 per replicate) and the time necessary to identify chironomids even to genus level, forced us to group the family as one unit. This problem obviously confounds results, owing to differing life histories within the group. Only trends can be followed. Figure 4.6 shows that, in spite of the fact that we analyzed an entire family, a trend emerged. Small size classes occurred during the fall and winter months (September through February). This is especially evident for FEX, the site with the highest numerical abundances for the family (see Fig. 4.3). Had we the time and finances to select a few species from the family, a more distinct pattern might emerge. FEX and FCD differences for this family may be owing to 1) A lack of summer cohorts for most species at FCD; 2) a predominance of summer species at FEX that are rare at FCD for some reason; or 3) poor growth and survivorship conditions at FCD for existing species. This coming year, we will endeavor to

75
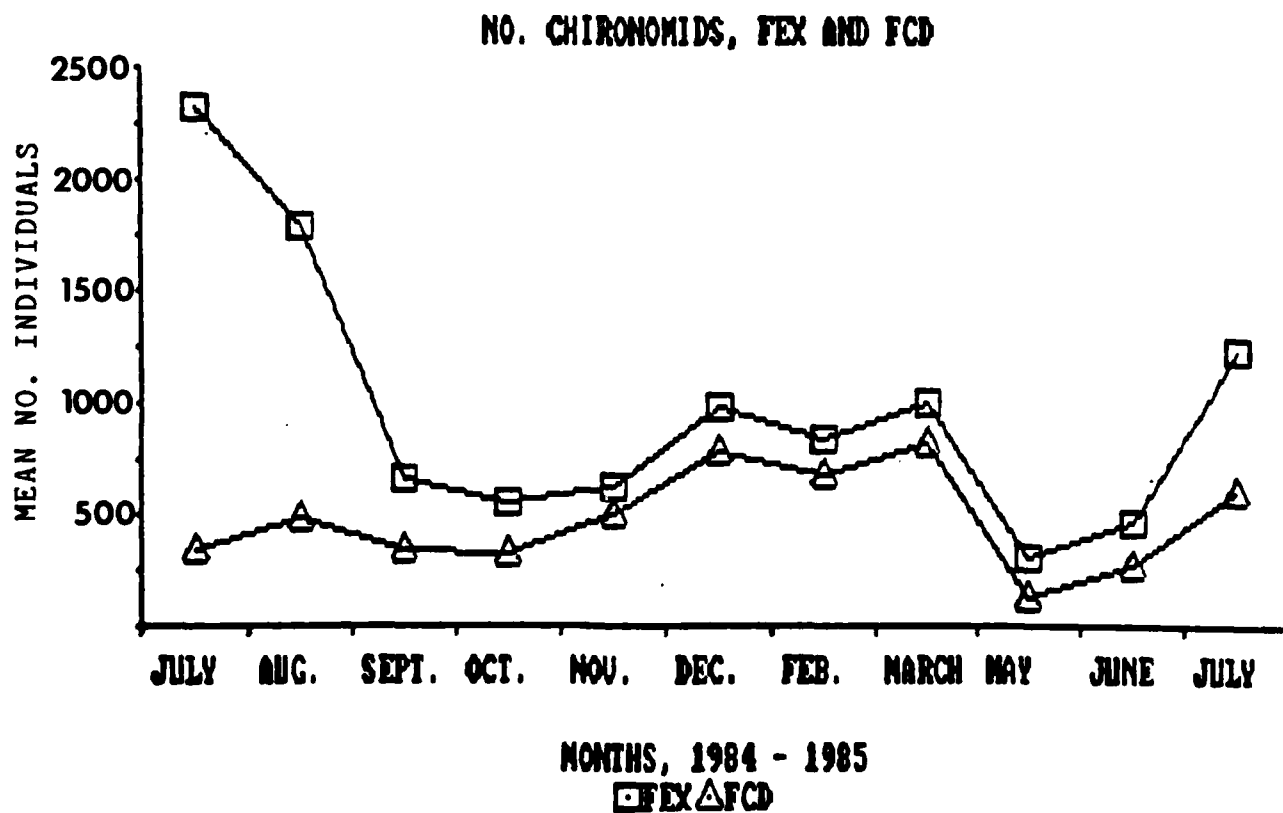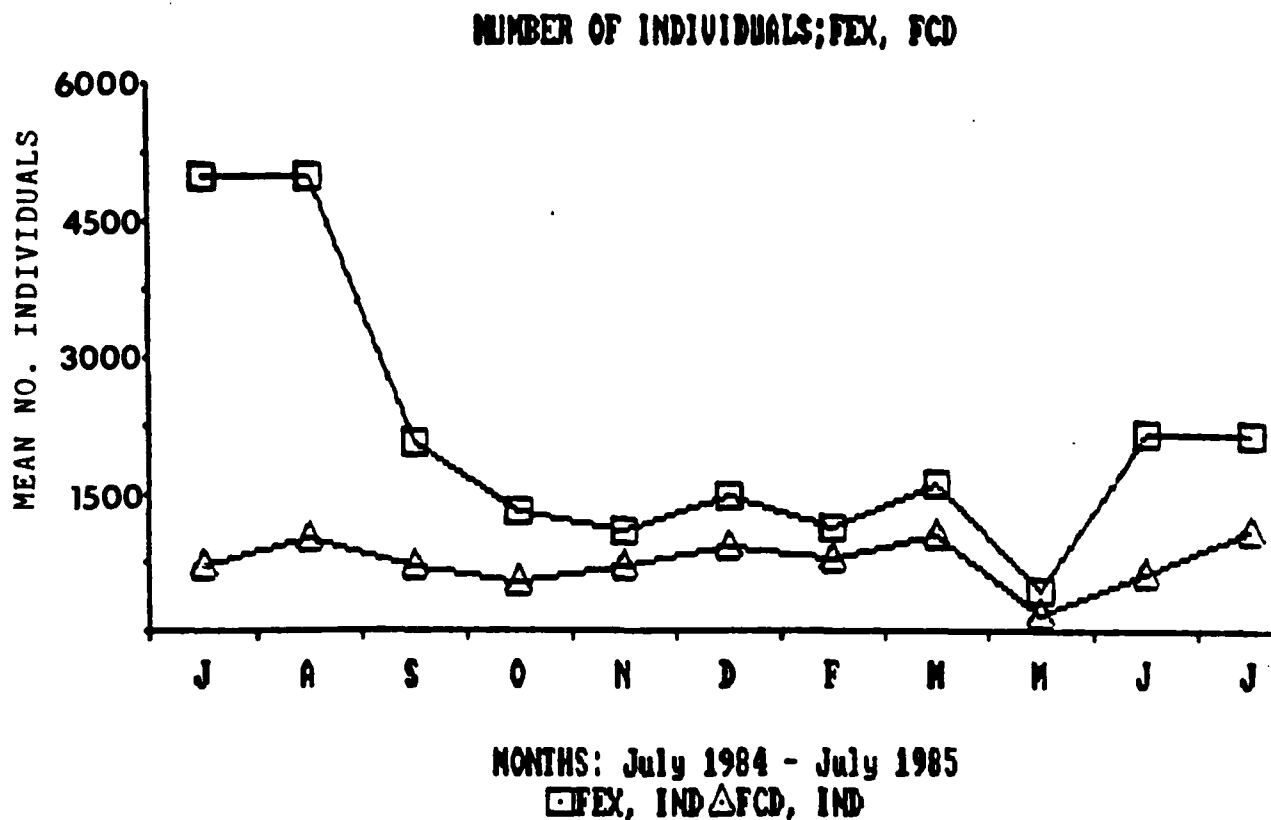
FIGURE 4.3 Total numbers of individuals and numbers of
chironomids at FEX and FCD, July, 1984 through July, 1985.

**FEX BIOMASS, 1984 - 1985**
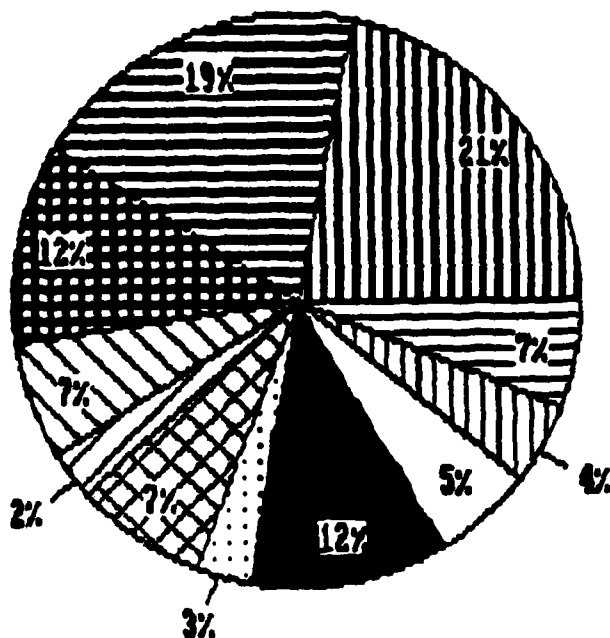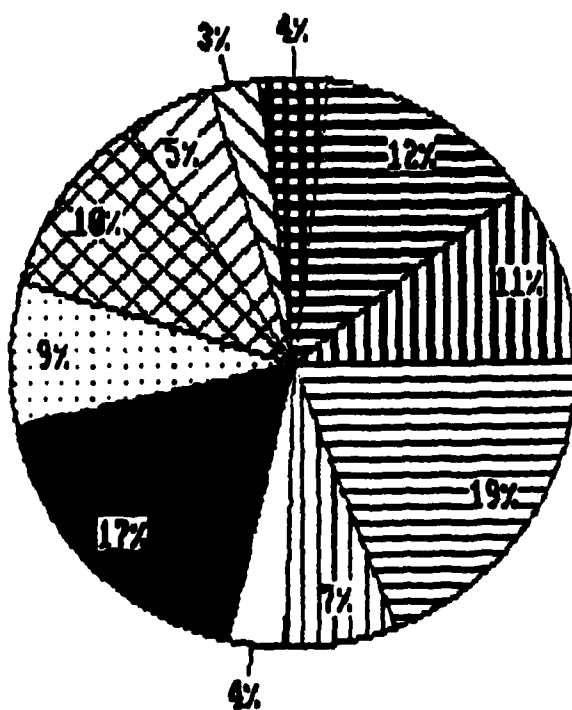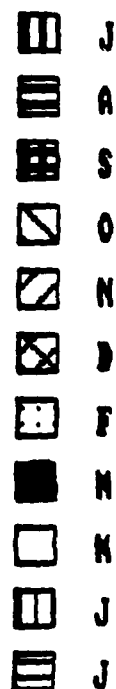
**FCD BIOMASS, 1984 - 1985**

FIGURE 4.4   Percent of total biomass apportioned for each month at FEX and FCD, July, 1984 through July, 1985.

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FCD, FEX, IND

J
A
S
O
N
D
F
M
N
J
J
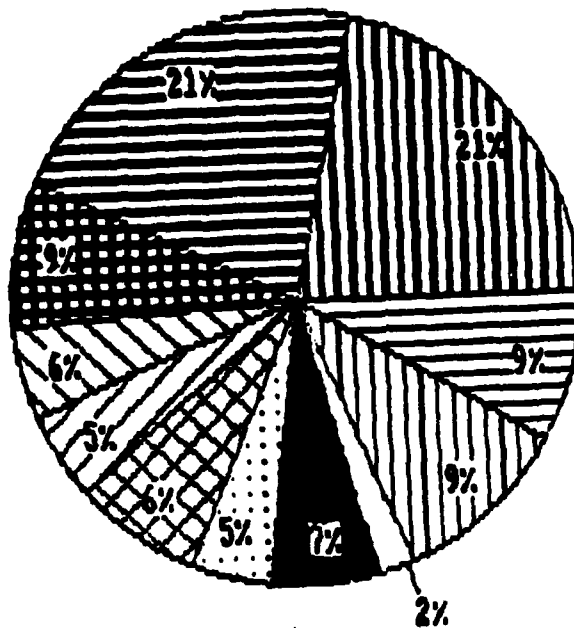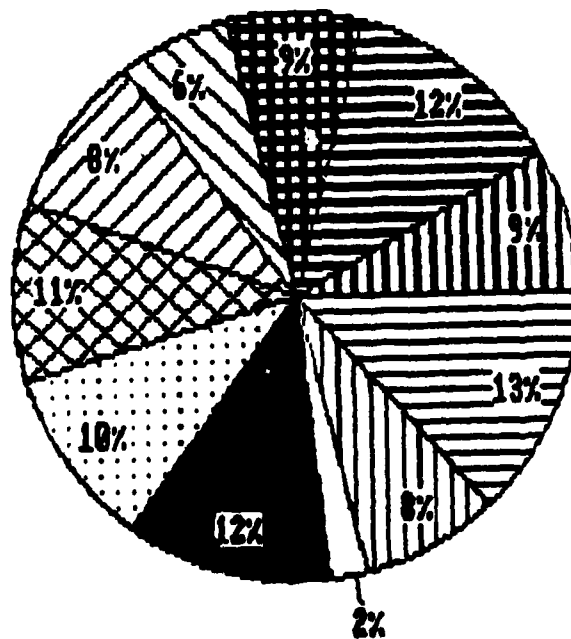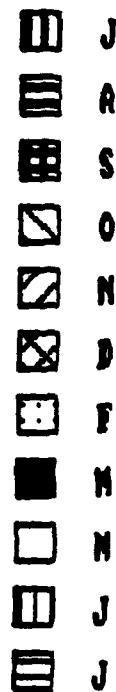
FIGURE 4.5  Percent of total numbers of individuals apportioned for each month at FEX and FCD, July, 1984 through July, 1985.

78
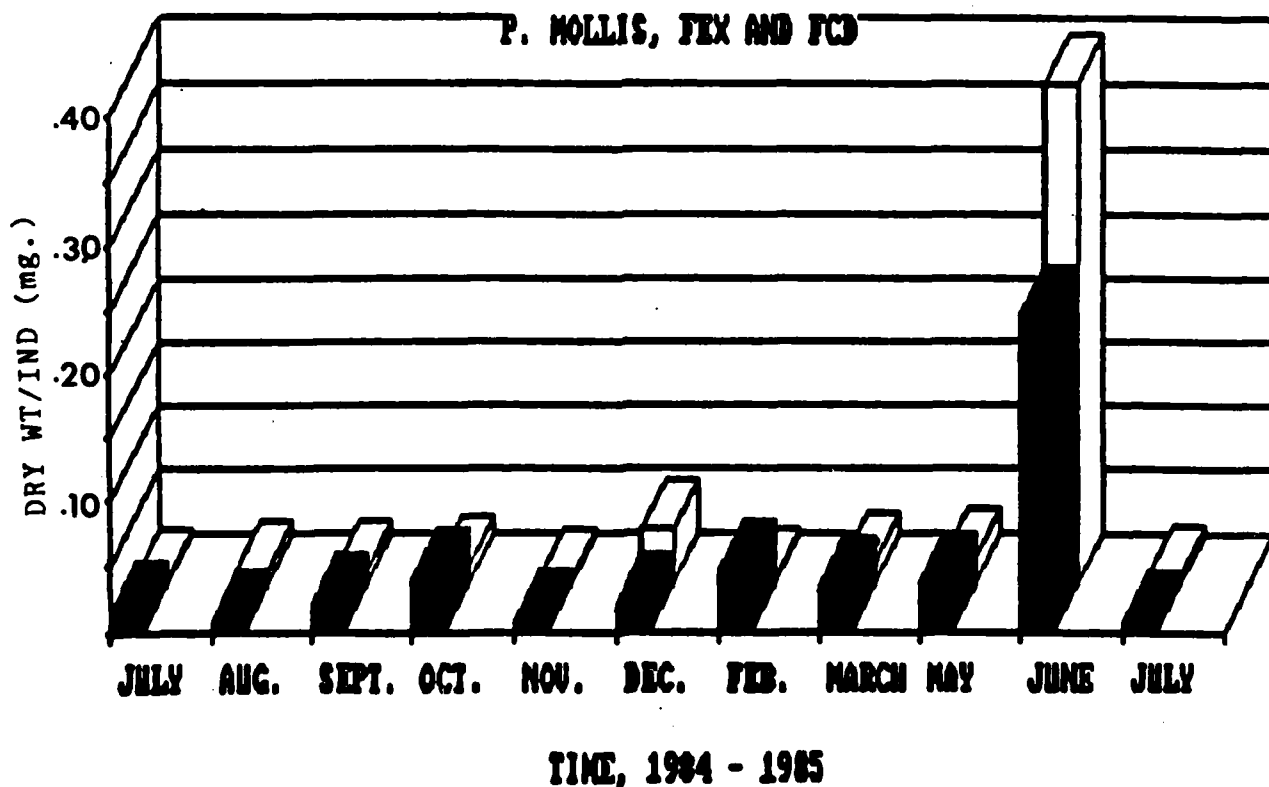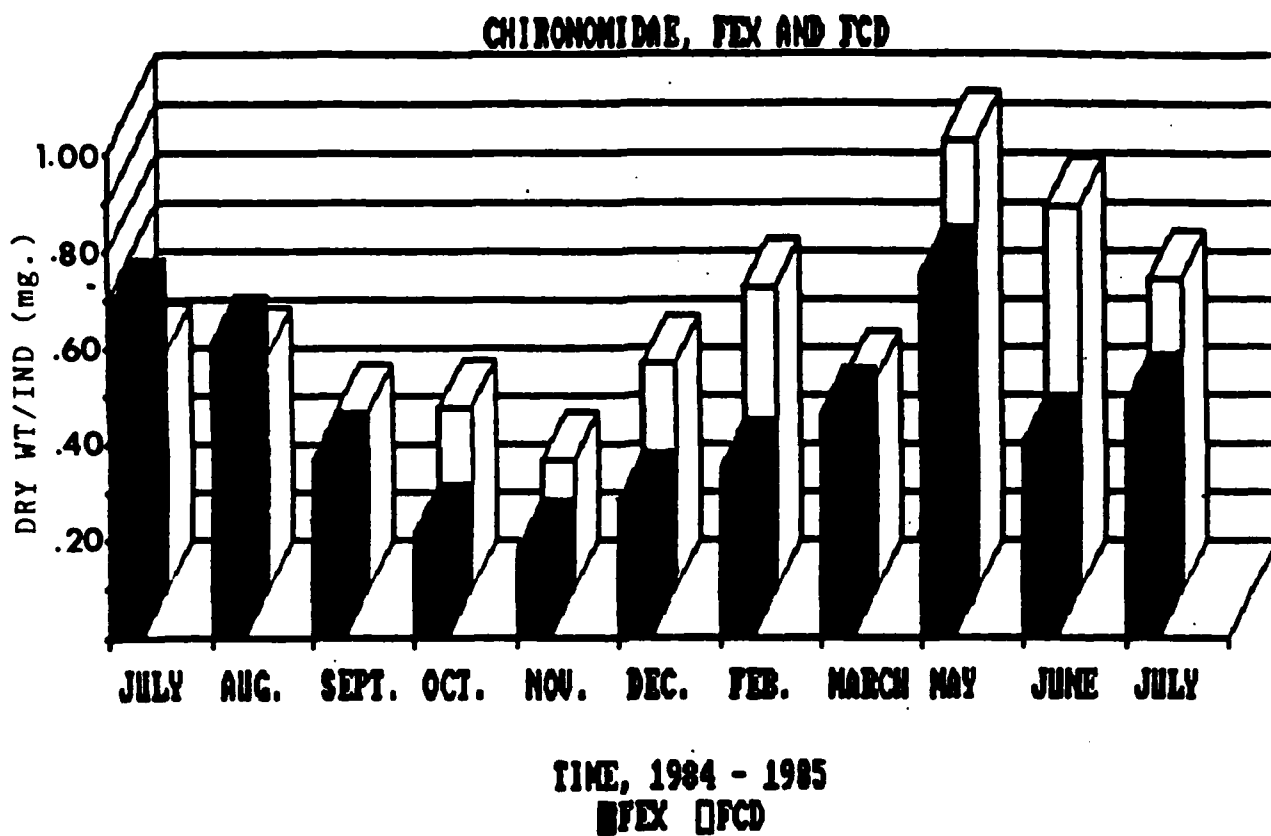
FIGURE 4.6 Dry weight per individual (mg.) for Chironomidae and Paraleptophlebia mollis at FEX and FCD from July, 1984 through July, 1985.

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select those easily identifiable species in an effort to glean more discrete information from the family.

b. <u>Paraleptophlebia mollis</u> (Eaton). A very distinctive size-class pattern emerges for this mayfly collector-gatherer (Fig.4.6). It appears to be univoltine, with its emergence being between late June and early July. Percent numerical dominance for this species was at its highest in September (7.13% at FEX and 11.37% at FCD). Its numerical dominance was less than 3% of the total number of individuals from November through May at both sites. This species shows similar size class patterns at both sites and it has been monitored since 1983. However, DW/IND values at FEX were higher than at FCD. Either growth and development of these populations are temporally out of phase at the two sites, or differences in the food base used by this species exist. Future amalgamation of temperature and periphyton data with insect data may allow more complete interpretation of the results.

c. <u>Ephemerella invaria</u> (Walker) and <u>Ephemerella subvaria</u> McDunnough. In the 1984 Annual Report, both species were treated together. In this report, they are treated separately. There are distinctive size class patterns for each species (Fig. 4.7). <u>Ephemerella invaria</u> was most abundant in October (1984) when its DW/IND value was very low. It appears to be univoltine, with its major emergence being in June and July. Either no animals of this species were found in July (at FEX at least) and August, or they were too small to be identified to species level. A comparison with data for this species from Element 6 data (leaf processing) shows that the size classes are similar (Compare Fig. 4.7 with Fig. 6.12), an expected result.

<u>Ephemerella subvaria</u>'s size class pattern is very consistent between sites. At its highest numerical abundance (September, 1984) it is at its smallest size class, indicating recent egg hatching. The growth pattern, as inferred from size class data, is smoothly ascending until after May, at which time, no individuals were found or identified as this species. (Small individuals often can only be identified to family level). Thus, each of the two species has a similar size class pattern at FEX and FCD. The two species will continue to be monitored. We will also try to collect and sex individuals of both species just prior to emergence. They will be weighed. Since females usually have twice the biomass as males at maturity, the separation by sex can add resolution to the biomass data and eliminate interpretation problems that can accrue from uneven male/female representation in samples.

c. <u>Optioservus</u> sp. No clear pattern emerges for this collector-gatherer elmid. On major problem lies in the fact

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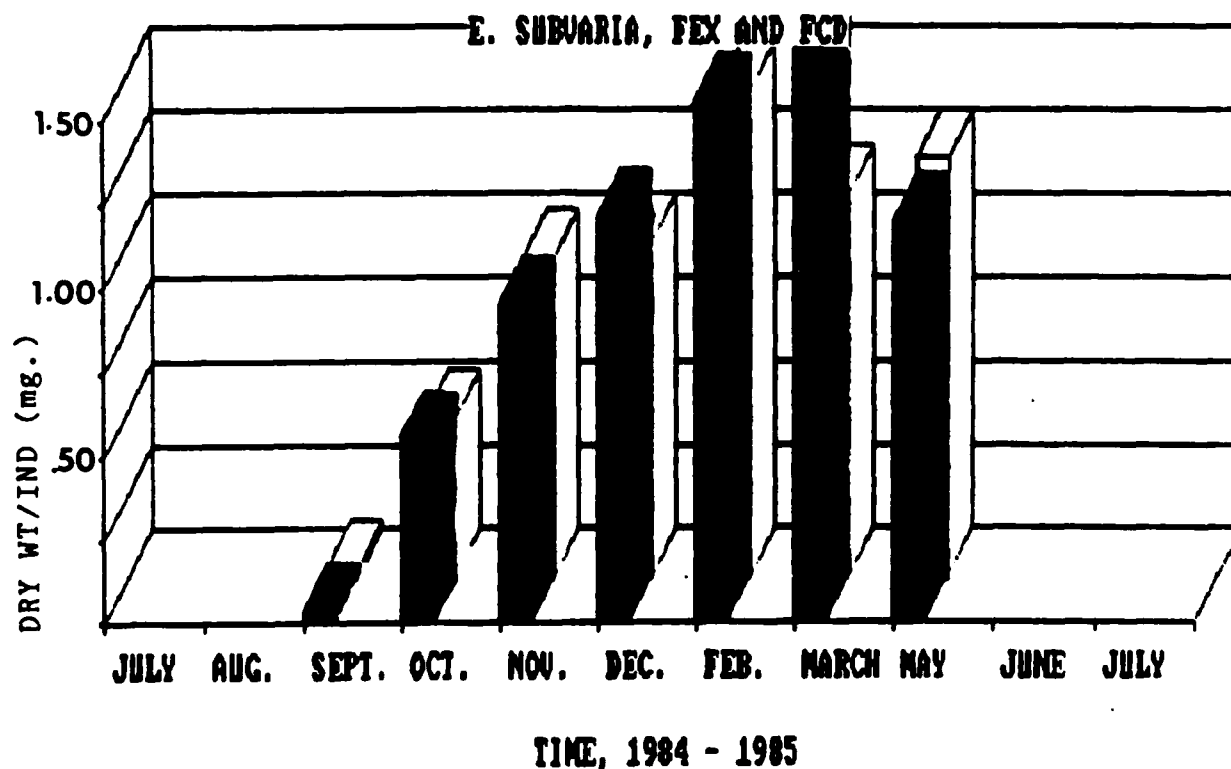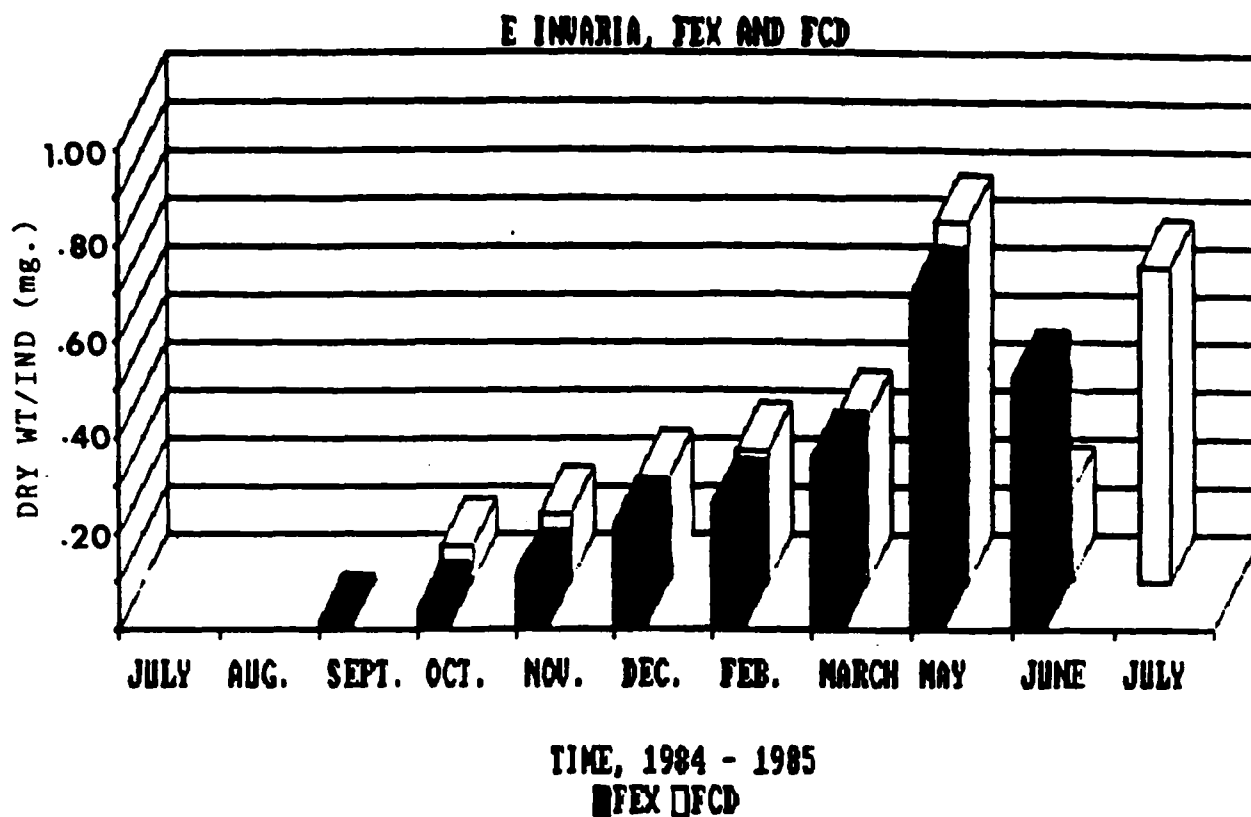
**FIGURE 4.7** Dry weight per individual (mg.) for _Ephemerella_ _invaria_ and _E. subvaria_ at FEX and FCD from July, 1984 through July, 1985.

that this genus is not univoltine. Even though this genus does not meet the criteria of having discrete generations, we will continue to use it, as it has high numbers and we can gather considerable information as to larval and adult numbers as the genus is holobiotic. There is a tendency for larger larvae to occur in the winter (Fig. 4.8). Certainly, from May through September, the DW/IND values are lower. The lowest adult to larvae ratios occurred from November through March (no samples were collected in April, owing to high water), and the highest adult to larvae ratios occurred from May through July (Fig. 4.9) in 1984-1985 and from April through June in 1983-1984 (See 1984 Annual Report.). (This animal can survive as an adult for more than a year.) Mean number of larvae and adults for the two site shown in Fig. 4.9 show that there is a trend downward for number of larvae from a high in August (at the beginning of our 1985 Annual Report data set) to a low in July, 1985 (the end of our 1985 Annual Report data set).

d. Tipula sp. The family Tipulidae was followed in 1983 - 1984 (Fig. 4.14, 1984 Annual Report) as well as in 1984 -1985. It is apparent from Figure 4.8 that there is no distinctive size class pattern for this genus. Further, the numbers of individuals in substrate samples are low and the variance is high. Tipulids have life histories that are difficult to follow, as they can be found in edges of banks and wet soil -- places we are not sampling. Likely, this genus will not be monitored in the future.

Comparisons with 1983 - 1984 Data

1. Structural Community Parameters.-- There is a general trend for taxon diversity values from November of 1983 (the date we began identifying taxa to lower levels) through July of 1985. The highest values were in the summer and early fall, with low points in the winter months (Fig. 4.10). This trend is most pronounced at FCD. Taxon Richness (S) is also the highest in the summer months (Fig. 4.10). (The low point in April of 1984 is probably owing to high water levels and difficulty in collecting samples; see 1984 Annual Report.) Water discharge and depths were high in April of 1985 as well (up to 14.5 cubic meters per sec.) and samples could not be collected. Richness values were similar for other times of the year. As for H', J' values were high in the summer and lowest during the winter (Fig. 4.10). Table 4.5 shows that the correlations between H' and J' were much higher than correlations between H' and S for both sites. Those values are slightly lower than values generated by July, 1984 to July, 1985 data, but the same trend holds -- the benthic insect community is in an unstable equilibrium, an expected result for running water systems.
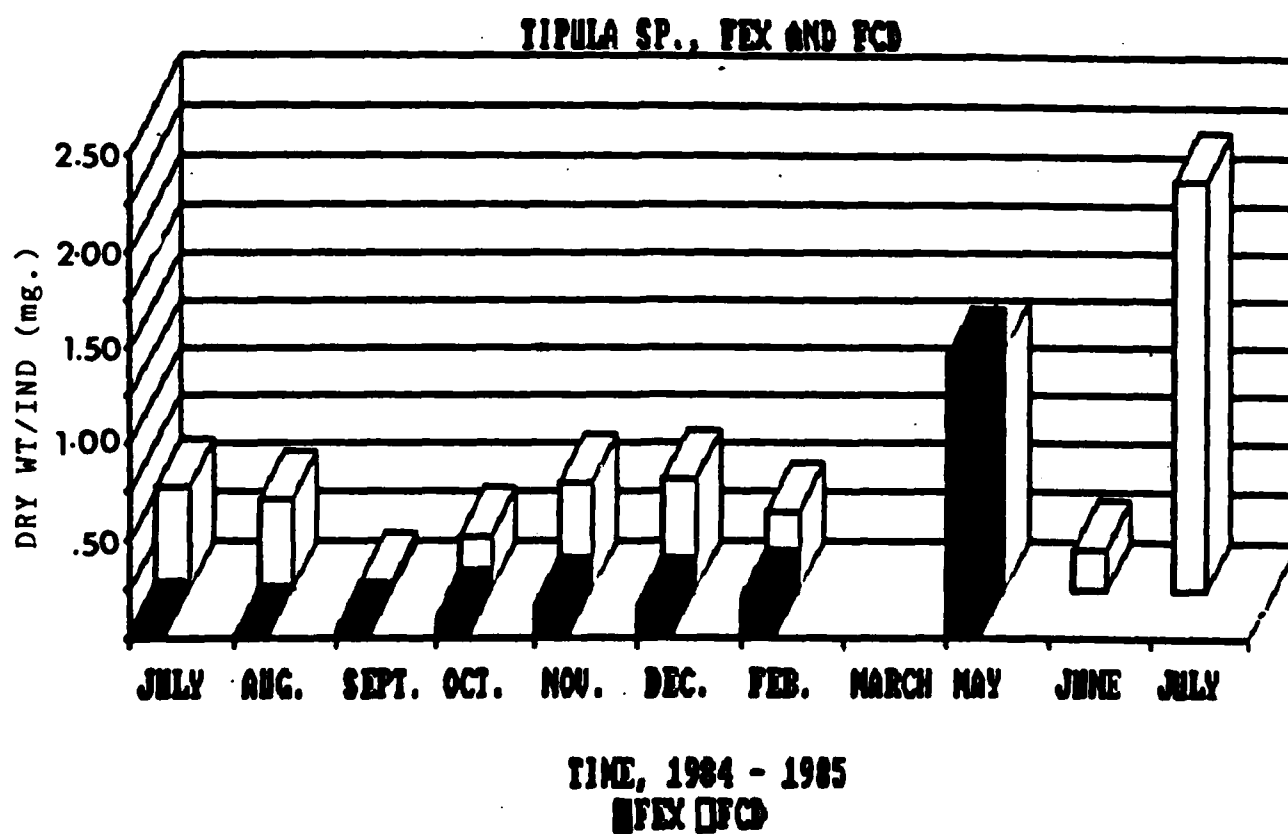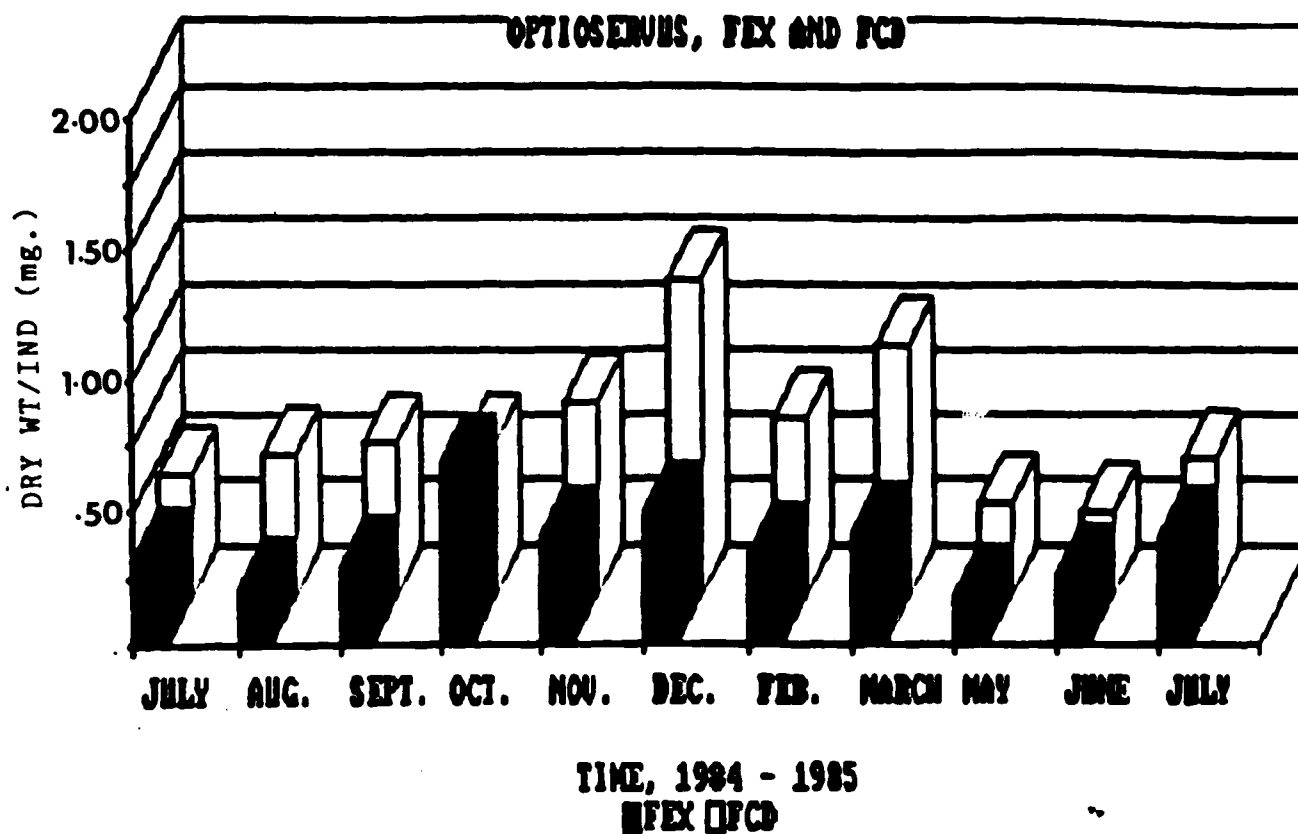
FIGURE 4.8 Dry weight per individual (mg.) for Optioservus and Tipula spp. at FEX and FCD from July, 1984 through July, 1985.

**OPTIOSERVUS LARVAE. FEX + FCD**

**OPTIOSERVUS ADULTS, FEX + FCD**
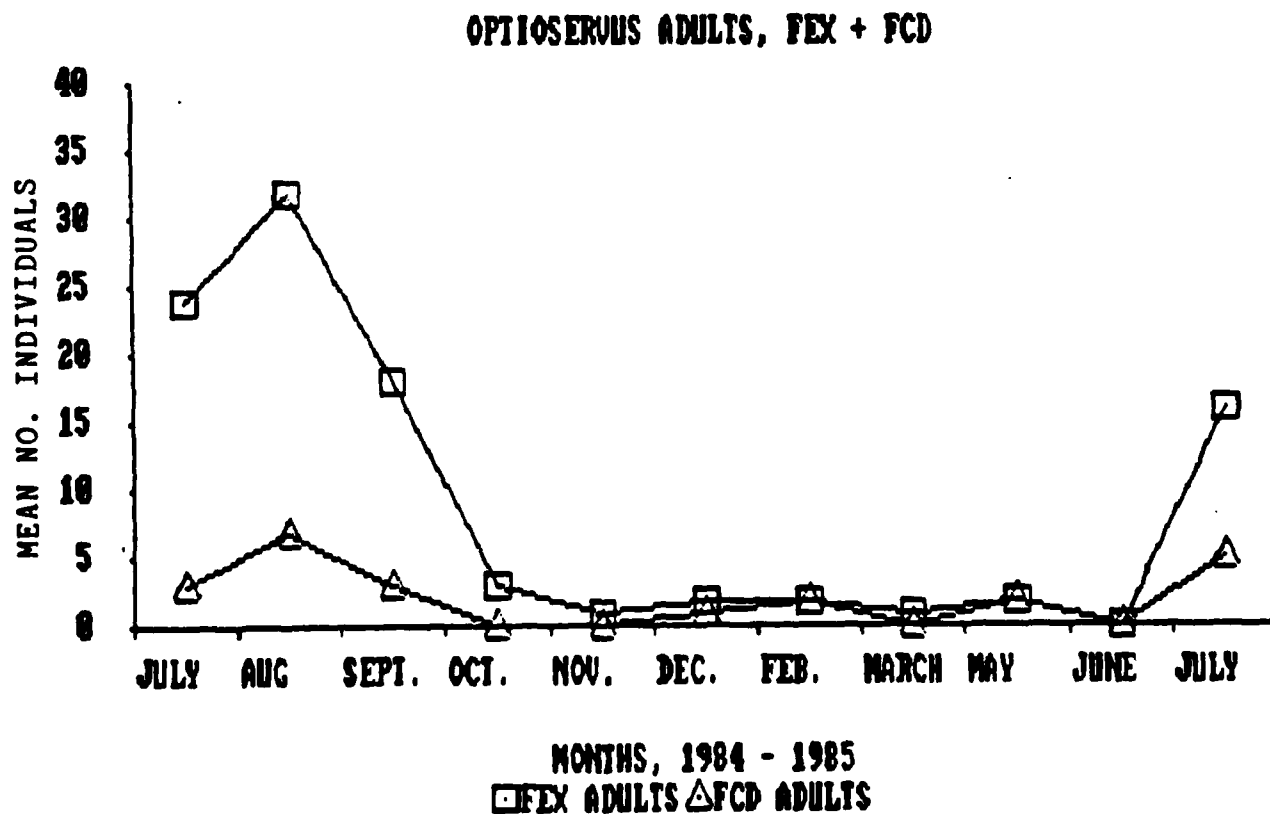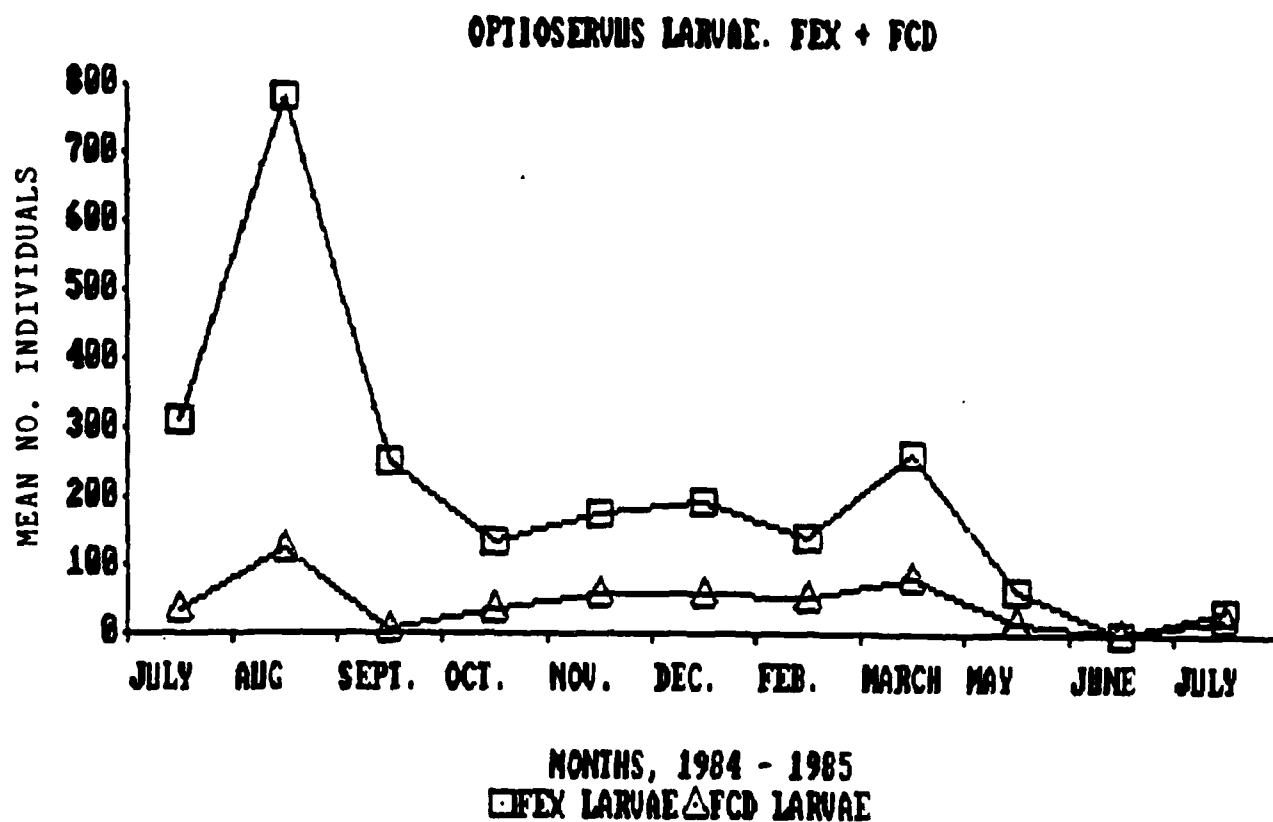
FIGURE 4.9  Mean numbers of larvae and mean number of adults of
<u>Optioservus</u> at FEX and FCD from July, 1984 through July, 1985.

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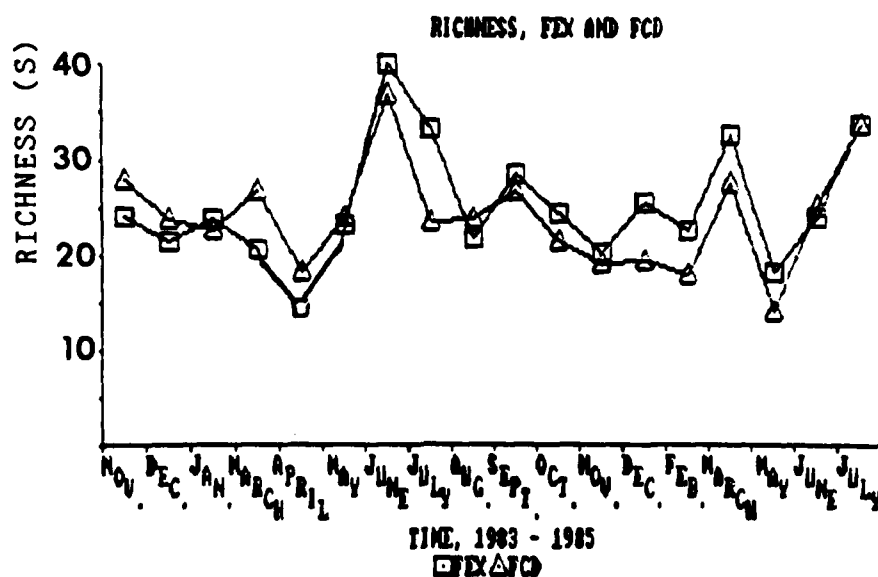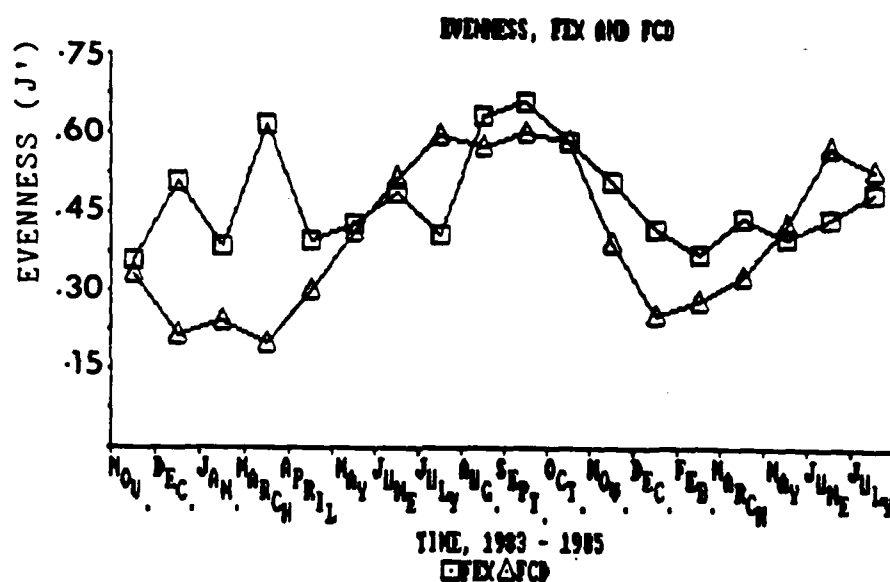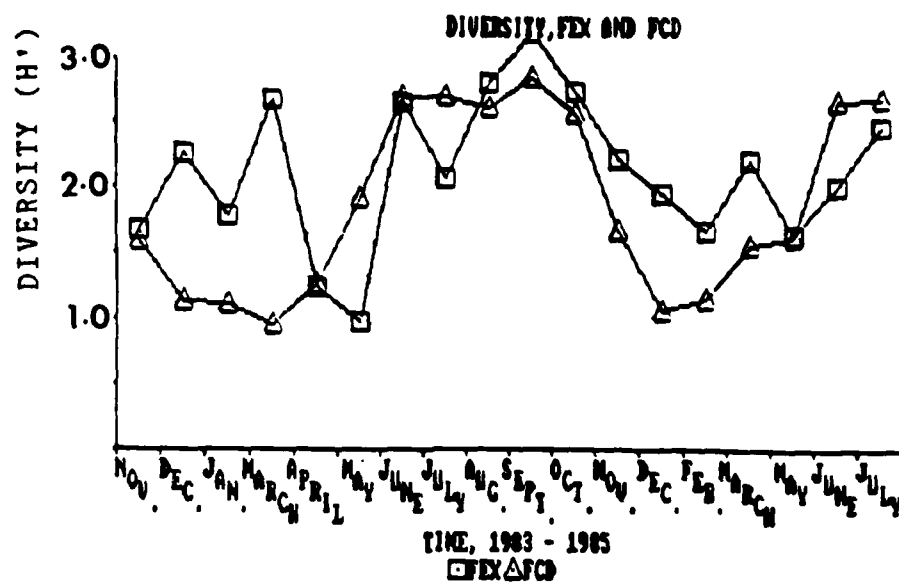
FIGURE 4.10   Taxon diversity (H'), evenness (J') and richness (S) at FEX and FCD from November, 1983 through July, 1985.

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## TABLE 4.5
### Correlation Matrix for S, H' and J' at FEX and FCD from November, 1983 to July, 1985

|        | FEX S | FCD S | FEX H' | FCD H' | FEX J' | FCD J' |
|--------|-------|-------|--------|--------|--------|--------|
| FEX S  | 1.00  |       |        |        |        |        |
| FCD S  | .71   | 1.00  |        |        |        |        |
| FEX H' | .47   | .45   | 1.00   |        |        |        |
| FCD H' | .52   | .46   | .50    | 1.00   |        |        |
| FEX J' | .12   | .26   | .84    | .40    | 1.00   |        |
| FCD J' | .41   | .29   | .43    | .98    | .36    | 1.00   |

As for 1983 - 1984 data, percent dominance and actual numbers of chironomids relative to other taxa remained the same -- chironomids affected H'and J' more than any other group, especially during the winter and early spring months (Compare Fig. 4.3 of the 1984 Annual Report with Fig. 4.2 in this report.).

2.  Functional Community Indices.-- Figure 4.11 shows changes in total insect biomass, diatom density and water temperature from June of 1983 through September of 1985. There are three distinct summer peaks and fall-winter troughs for all three paramters. The summer peaks dropped through the three years for all parameters. Possibly, the mean lower water temperatures affected the biological parameters. For the insect total biomass data, the means were not independent of the variances and a natural log transformation was performed on the data prior to regression analyses (Table 4.6).

## TABLE 4.6
### Linear Regression Analysis for Insect Biomass, Diatom Density and Water Temperature, 1983 - 1985

| A. 1983 - 1985 | $r^2$ | Significance |
|----------------|------|--------------|
| Insect Biomass vs. Diatom Density | .467 | $p<.0001$**** |
| Insect Biomass vs. Water Temperature | .442 | $p<.0001$**** |
| Diatom Density vs. Water Temperature | .521 | $p<.00001$**** |

| B. June 1983 - May 1984 | | |
|----------------|------|--------------|
| Insect Biomass vs. Diatom Density | .610 | $p<.005$*** |
| Insect Biomass vs. Water Temperature | .678 | $p<.002$*** |
| Diatom Density vs. Water Temperature | .723 | $p<.009$*** |

| C. May 1984 - June 1985 | | |
|----------------|------|--------------|
| Insect Biomass vs. Diatom Density | .548 | $p<.01$* |
| Insect Biomass vs. Water Temperature | .678 | $p<.03$* |
| Diatom Density vs. Water Temperature | .389 | $p<.05$* |
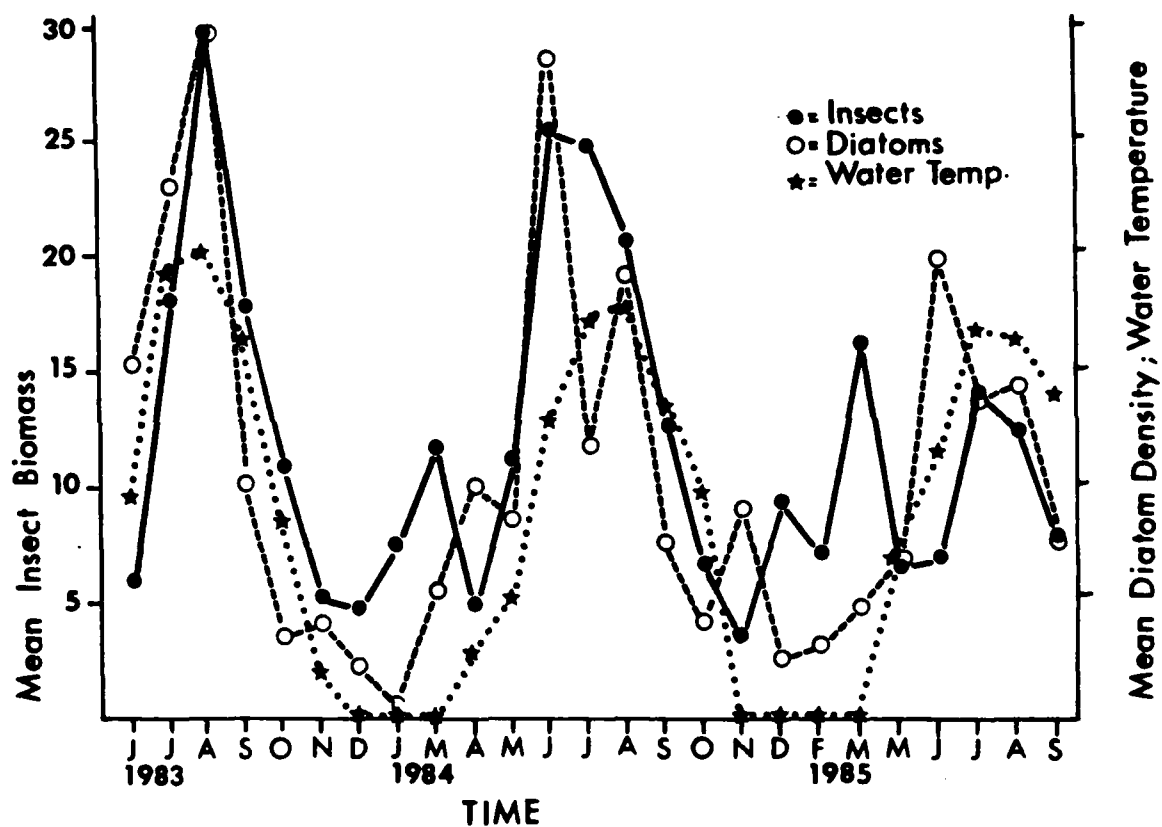
FIGURE 4.11   Changes in insect mean total biomass (mg./sample
X 10-1),   diatom density (number per square meter X 10-8),
and water temperature (degree Cent.)for FEX and FCD combined.
June, 1983 through September, 1985.

Not only were the regression coefficients high for the linear regressions, but the levels of significance were very high as well. In the future, other ambient monitoring data (including discharge levels) will be analyzed with respect to the biological parameters. The ambient monitoring data will be analyzed for dates two weeks prior to collection of biological samples to see if the environment prior to collection is more important (i.e., reduces the variance even more) than just at collection times. Because the trends appear to be so predictable, certainly further work along these lines will be done.

Insect total biomass values were separated according to functional feeding groups to see which groups had the most influence on the total biomass patterns. Figure 4.12 shows that the seasonal pattern for predator biomass resembled the total insect biomass pattern (Fig. 4.11). Collector filter-feeders also showed summer peaks in winter troughs in 1983 and 1985 (Fig. 4.12). Collector-gatherers fluctuated more, and shredders showed no obvious seasonal pattern (Fig. 4.13). Statistical analyses for functional feeding groups will be performed for the next Annual Report.

Dry Weight values per individual (DW/IND) for select families and species were performed. The pattern for chironomids was less distinct in 1984-1985 (Fig. 4.6) than in 1983-1984 (Fig. 4.14). Even so, similar trends were found. Smaller individuals were found in the winter months than in the summer months for both data sets. Paraleptophlebia mollis had similar size class patterns from July, 1983 through July, 1985 (Fig. 4.14). Animals were small until June, at which time the species more than doubled in size.

Ephemerella invaria and E. subvaria were separated in 1984-1985. The 1983-1984 DW/IND data look more similar to data for E. invaria, which is expected as that species was more common than E. subvaria (Fig. 4.15). Patterns for the two species are distinctive. The apparent increase in size for the genus in October of 1983 (Fig. 4.15) is likely attributable to E. subvaria, the larger of the two species. It now appears that both species are univoltine, with E. invaria emerging in June to July and E. subvaria emerging in May to June (Fig. 4.7).

Optioservus is at its largest size from October through March (Fig. 4.16). Tentatively, it appears that most reproduction occurs in the summer, with most of the growth occurring during the winter. Variation for a shredder, Tipula, is too high for interpretive purposes. This may be owing to two factors -- too high of a taxonomic category and too few animals in substrates during the summer months.

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FIGURE 4.12   Changes in predator and filter-feeder biomass
(mg./sample) at FEX versus FCD.   June, 1983 through Sept.,1985.
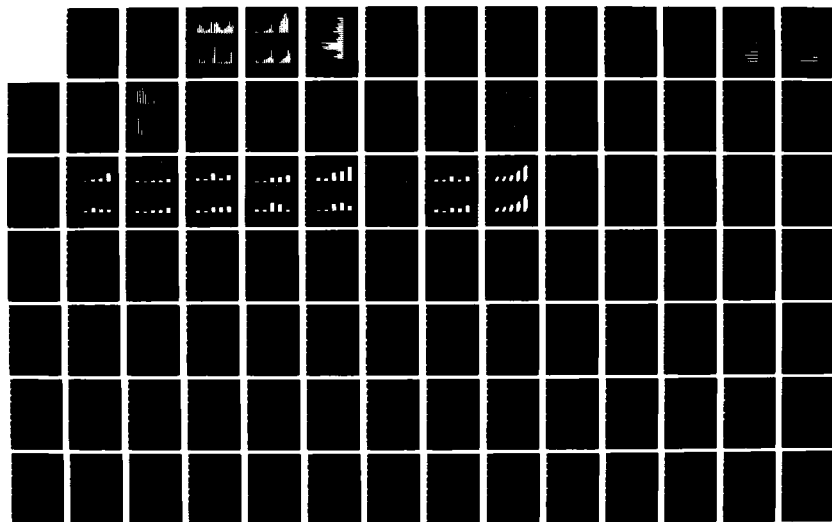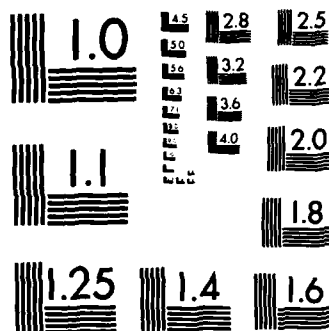
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A
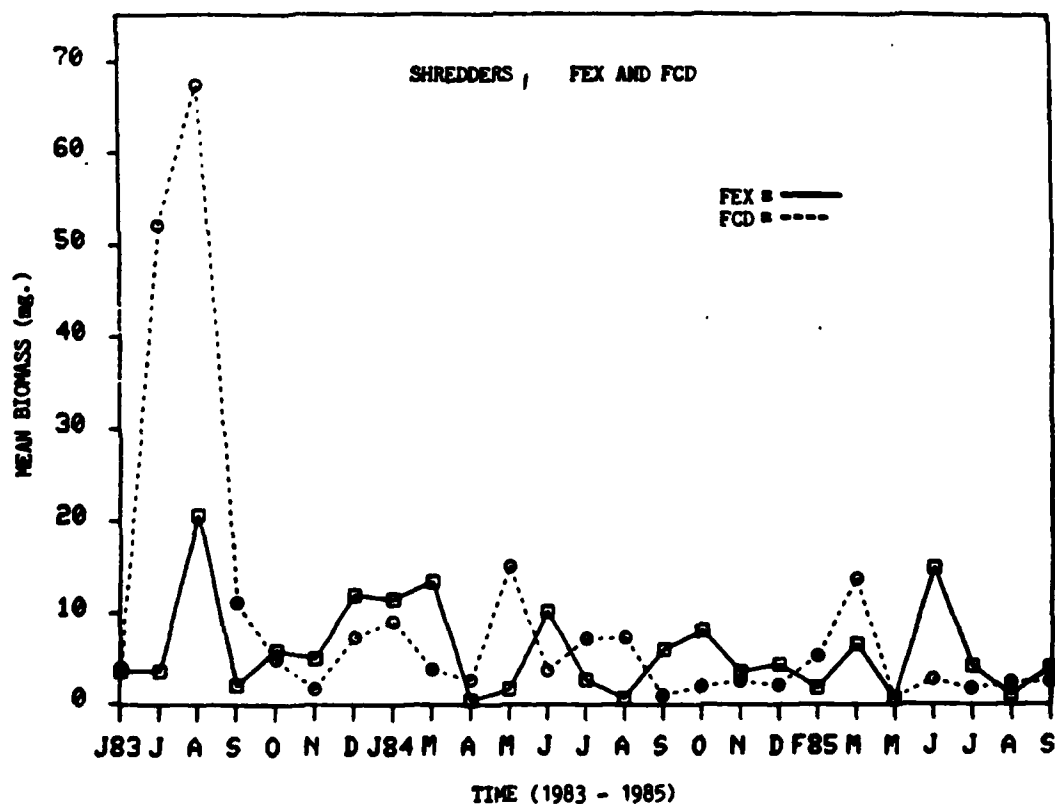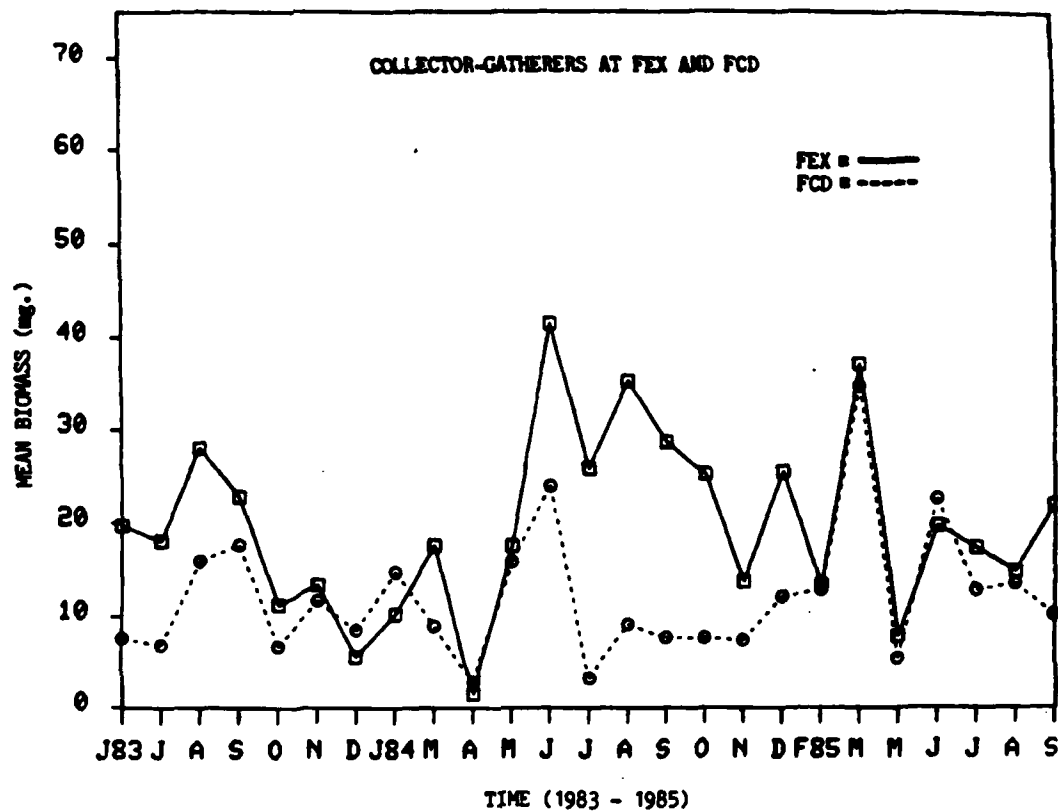
FIGURE 4.13 Changes in collector-gatherer and shredder biomass (mg./sample) at FEX versus FCD. June, 1983 through September, 1985.
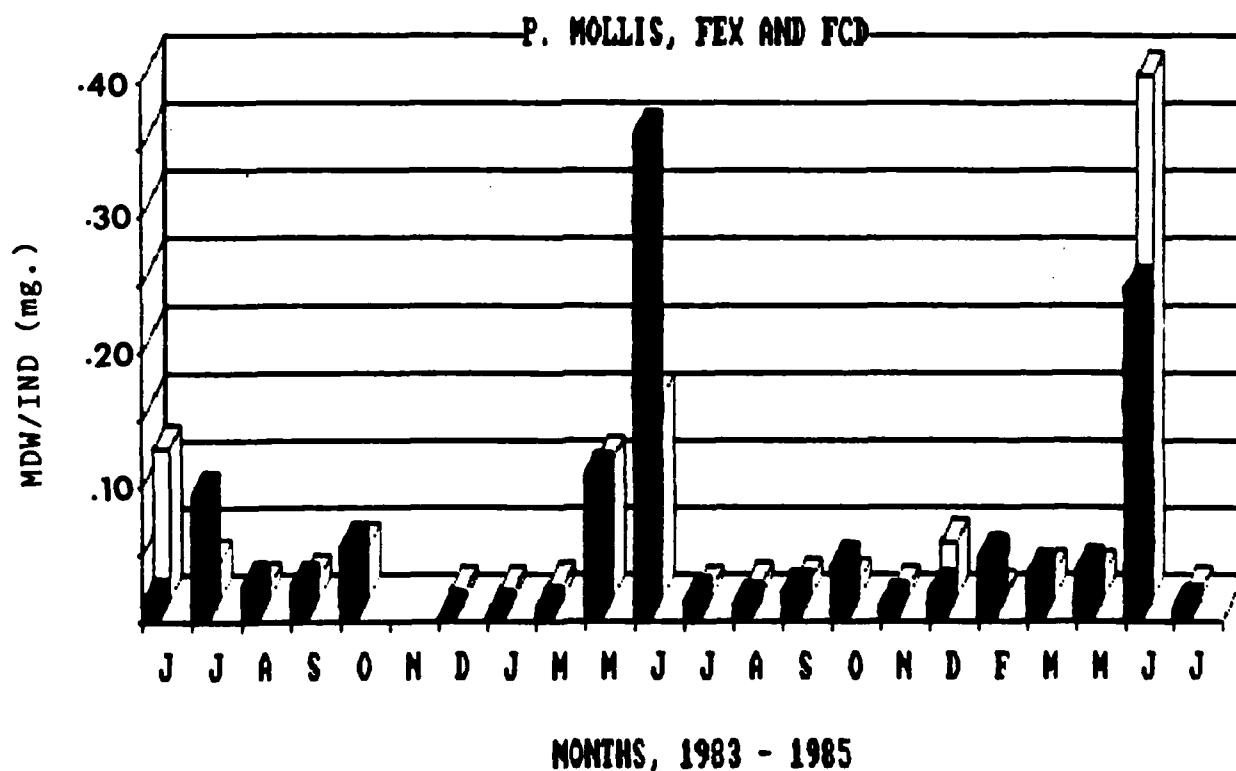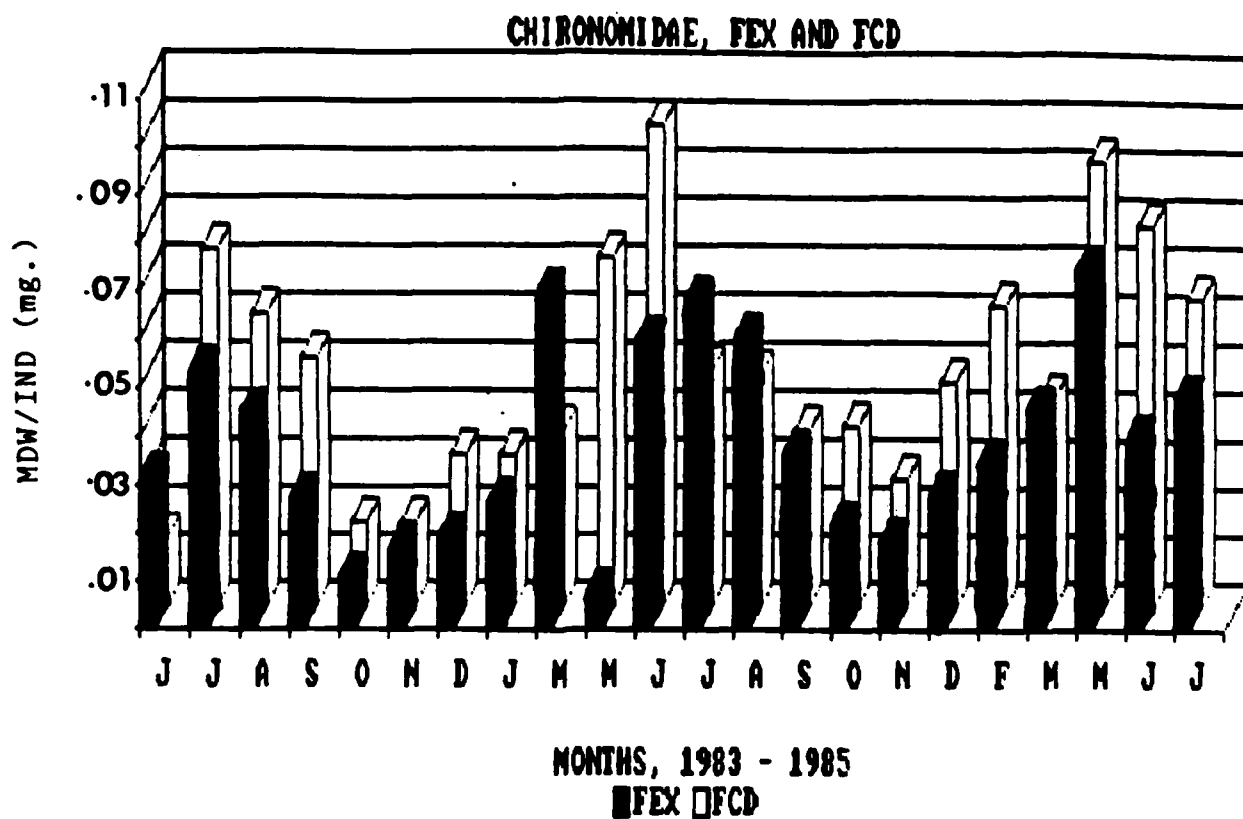
FIGURE 4.14 Mean dry weight per individual for Chironomidae and _Paraleptophlebia mollis_ at FEX and FCD from June, 1983 through July, 1985.
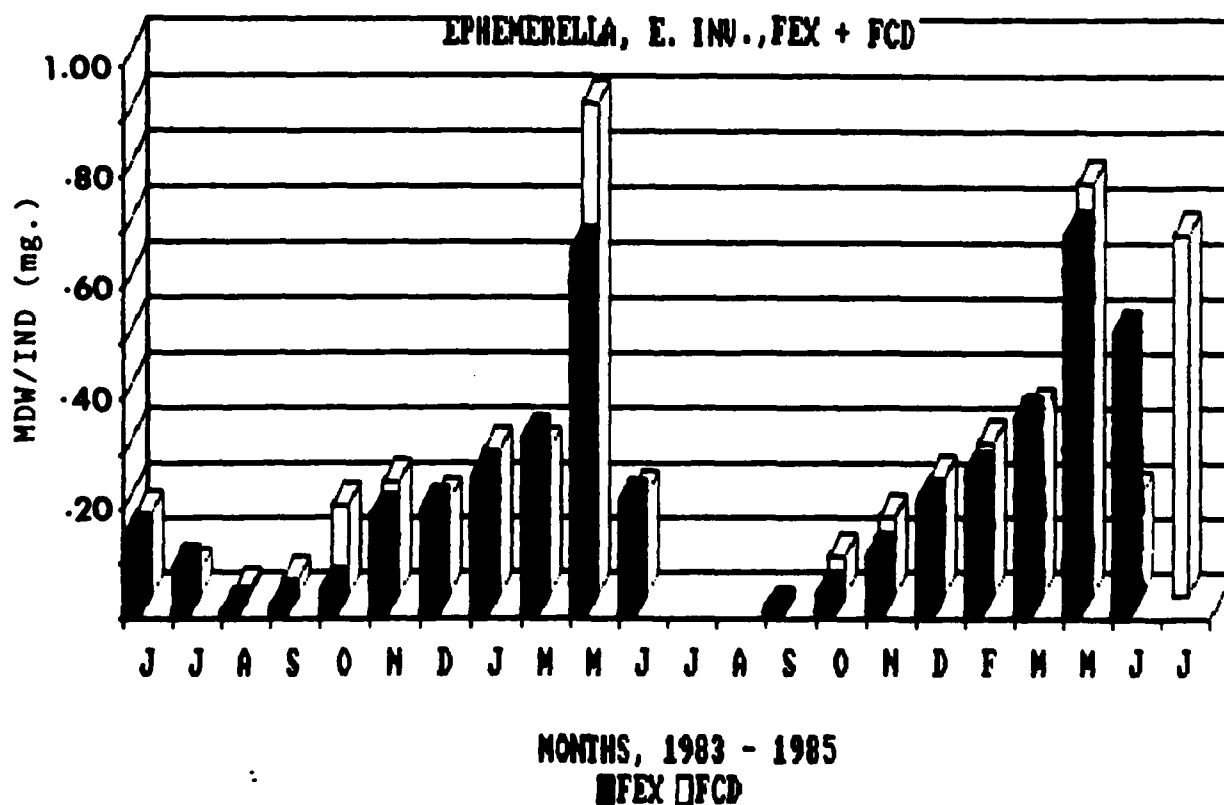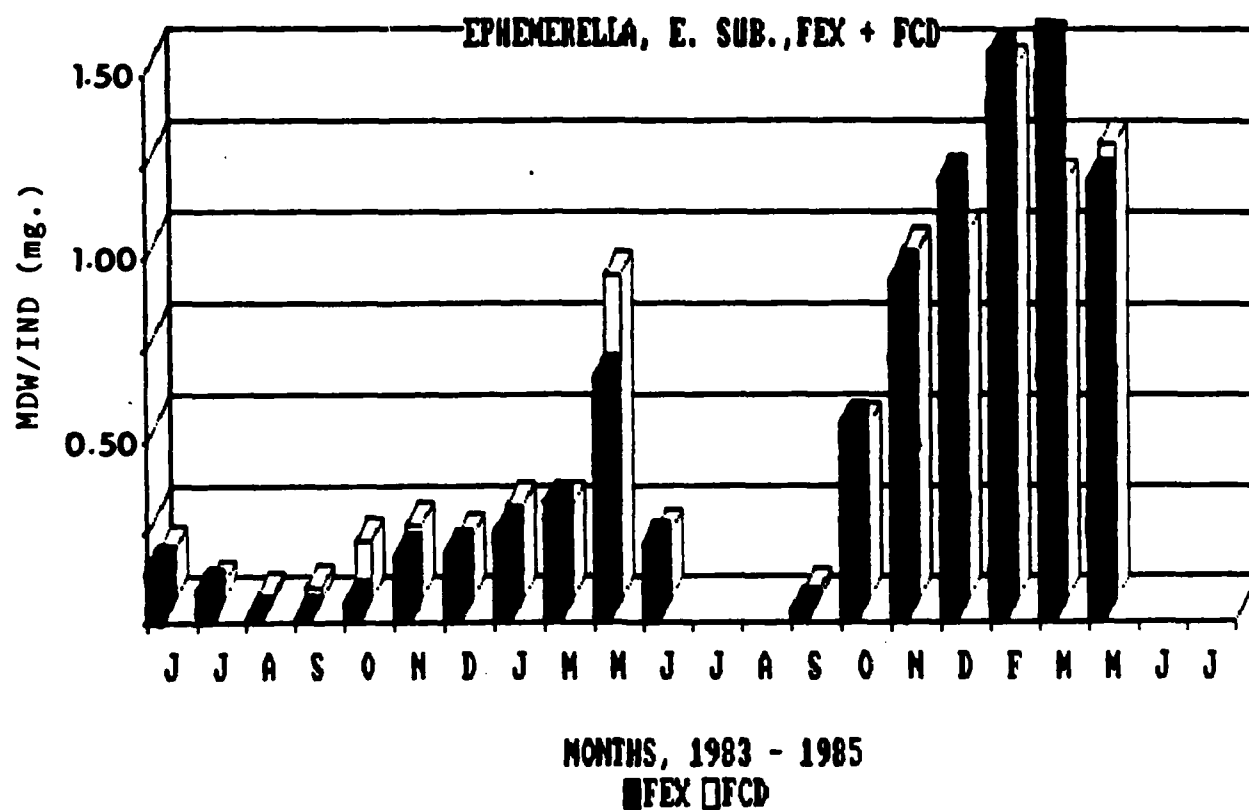
FIGURE 4.15 Mean dry weight per individual for Ephemerella, Ephemerella subvaria and Ephemerella invaria at FEX and FCD from June, 1983 through July, 1985.

**OPTIOSERVUS, FEX AND FCD**

MDW/IND (mg.)

MONTHS, 1983 - 1985

■FEX □FCD
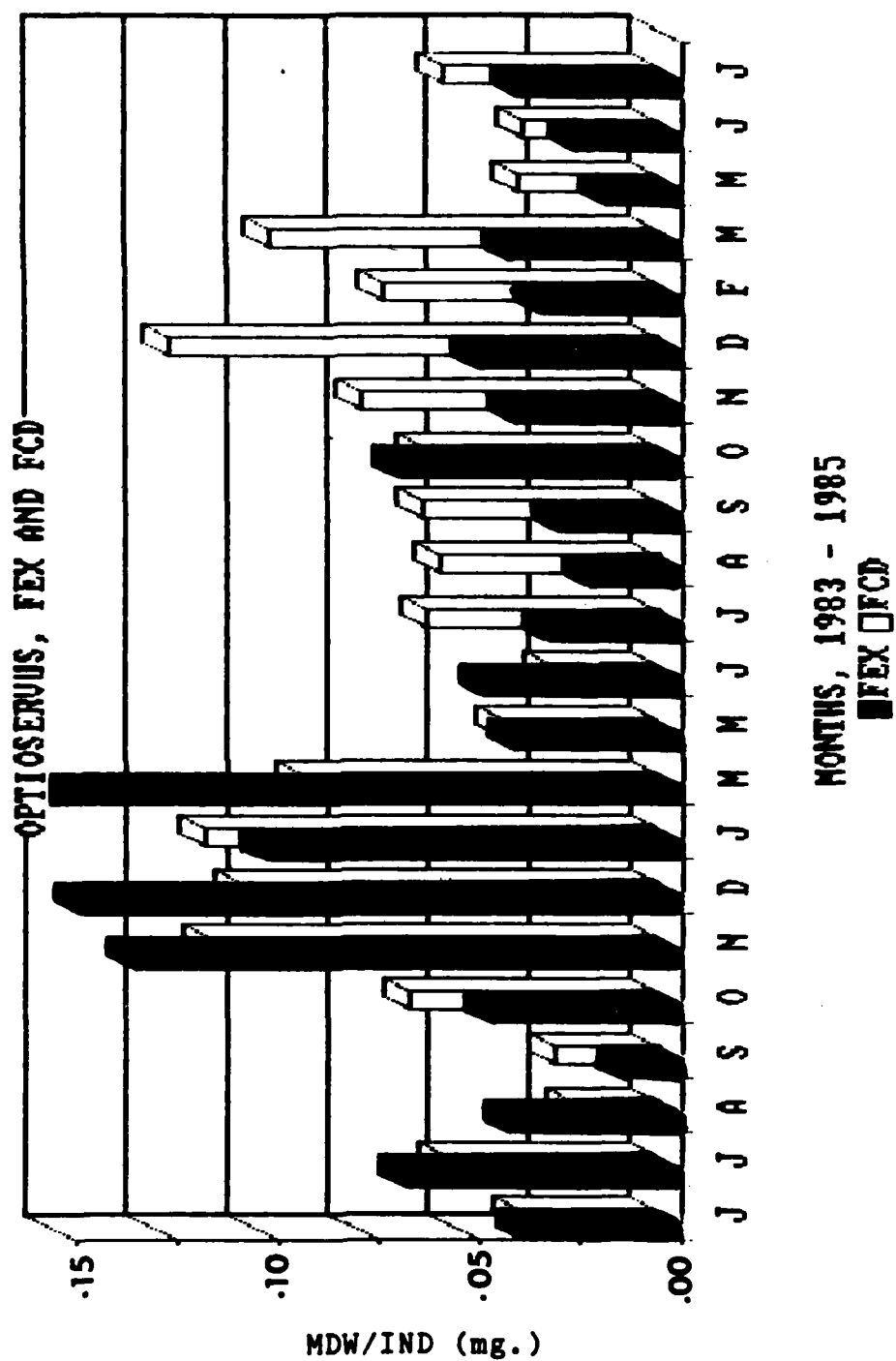
FIGURE 4.16  Mean dry weight per individual for <u>Optioservus</u>
at FEX and FCD from June, 1983 through July, 1985.

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## Summary

Taxon diversity (H') and evenness (J') from 1983 to 1984 were highly correlated with one another. Both parameters had their highest values in the summer months and their lowest values during the winter months. High chironomid abundances greatly affected H' and J' and are highly correlated with those two parameters. If chironomids were excluded from benthic insect analyses, very different values for H' and J' would emerge.

Distinct seasonal patterns were found for insect total biomass over a three year period. These patterns were highly correlated with diatom densities and water temperatures at FEX and FCD combined. These seasonal patterns will be investigated further with additional ambient monitoring data. Future data will be incorporated, using the same analyses.

Biomass values, when coupled with numerical abundances of certain taxa, showed low in variance over time. The following taxa showed consistent size class patterns (DW/IND) from 1983 to 1985 at both sites: Chironomidae, Paraleptophlebia mollis, Ephemerella invaria, E. subvaria, and Optioservus sp. They will continue to be monitored. Because Optioservus is not a univoltine genus but both adults and larvae are found in samples, separate analyses as to adult/larval ratios will be performed. DW/IND data for this genus is less reliable than those data for other species, given the fact that there is generation overlap.

Beginning in June of 1986, we will take seven replicates per site at each collection date. As the variance is higher but numbers of individuals lower during the winter than at other times of the year, we will sample every 45 to 60 days during the winter and will collect 10 replicates per site.

## Literature Cited

Merritt, R. W. and K. W. Cummins, 1984. An introduction to the aquatic insects of North America. Kendall/Hunt Publ. Co., Dubuque, Iowa, 722 pp.

Smock, L. A., 1980. Relationships between body size and biomass of aquatic insects. Freshwater Biology. 10:375-383.

Tramer, E.T., 1969. Bird species diversity: components of Shannon's formula. Ecology. 50:927-929.

## Element 5 - Movement Patterns of Selected Aquatic Invertebrates

Changes from the Original Synopsis - None.

### Objectives

To monitor short-term movement patterns of a dominant insect predator, the dragonfly Ophiogomphus colubrinus.

Just as extremely low frequency waves can affect the orientation and movements of birds, mammals and fish, it can also affect movements and orientations of aquatic insects. We selected a highly abundant predator whose normal travel distances are short enough (5 m per 24 hr) to study feasibly. If E.L.F. alters orientation and movements rates of this predator, we expect (given the numbers of individuals and recapture success) to be able to detect differences, if they occur, under the influence of E.L.F.

### Materials and Methods

In July and again in August, 1985, movement studies of naiads of the dragonfly, Ophiogomphus colubrinus, were conducted at FEX and at FCD. The same riffle at FEX (directly upstream from the ambient monitoring station) was used in 1984 and 1985. The riffle used at FCD was 160 m downstream from the ambient monitoring station there. (No mark-recapture studies were done there in 1984.)

Prior to initiating mark-recapture studies, one-meter square grids were established, using flagged metal stakes. Flow rates, direction of flow, and water depths were taken, using the stakes as reference points. Flow rates were determined with a Gurley Flowmeter; three rates were taken and means determined for each location. Flow direction was mapped by placing an orange between each upstream stake and tracking the orange's course downstream. Directions were taken twice prior to initiation of each mark-recapture series. Depths were taken at one meter intervals along four transects, which were four meters apart.

Naiads were then collected downstream of the riffle, using a one meter square handscreen. The naiads were placed in a holding pan with stream water until sufficient numbers had been collected. No naiads smaller than 9mm were used. Naiads were removed from the holding pan, measured, blotted dry with a "Kimwipe", and marked with Testors enamel paint on the dorsal and lateral surfaces of the abdomen. They were placed in a second holding pan for approximately five minutes to allow the paint to dry. After drying, the naiads were placed in a third holding pan with stream water to test the adherance of the paint. Those individuals on which the paint did not adhere were remarked as described above.

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Naiads were released in the upper end of the study grid one meter square area (figs 5.1, 5.2). The holding pan, containing the marked individuals, was placed in the stream at the upper end of the release area. Naiads were allowed to wash out of the pan to drift downstream. Some made contact with the substrate and held on. Those that continued to drift were captured in a kickscreen held one meter downstream from the release site. The kickscreen was then laid parallel to the substrate surface, with the upstream side facing the substrate. The naiads on the screen were allowed to crawl from the screen to the substrate. A second screen was held 1m downstream from the first and 2m from the original release site. Naiads that failed to hold onto the substrate were collected on this screen. Those naiads were placed by hand on the substrate in front of the screen and they were observed with a facemask to assure that they did not release and drift downstream.

Twenty-four hr after the initial release, the grid was kickscreen sampled in 1m square areas. The number of marked individuals and unmarked individuals collected from each square of the grid were recorded and these naiads were placed in a holding pan. After the entire site was kicked, leaving a border of at least 1square meter where no marked animals were recaptured, all previously marked animals were remarked with a new color. Additional unmarked animals were marked, giving a total of at least 220 individuals. All animals were again released at the original release site. Forty-eight hr later, the area was resampled. The 48 hr recaptured animals were those with the second day marks. The 72 hr recaptured animals were those marked the first day of the study. Percent recapture success and location of recaptured animals were determined. Population estimates, based on 24 hr data, were computed using the Lincoln Index Method (see Southwood, 1966).

Twenty-four, 48 and 72 hr mark-recapture studies at FEX were done from 8 to 11 July; FCD studies were done from 15 to 18 July. In August, recaptures after 24 hr only were done from 1 - 2 August at Fex and from 9 - 10 August at FCD.

## Results

Physical Differences Between FEX and FCD.-- Mean velocities were lower at FEX than at FCD (FEX: 36 cm/sec., FCD: 42 cm/sec., t = 1.93, d.f.22, p =0.034). Mean water depth was significantly greater at FEX than at FCD (FEX = 29.3 cm., FCD = 22.2 cm.; t = 4.67, d.f.84, p <.001).The bottom contour was less variable at FEX as well (C.V. at FEX = 33.71%; C.V. at FCD = 39.92%). The maximum width at FEX was narrower (10.6m vs. 11.7m at FCD). Finally, the percent of the meter square grids containing rubble as opposed to

# FEX SITE



FIGURE 5.1

Mark-recapture site at FEX. Curved lines depict flow patterns
Asterisk represents release site. Values are numbers of recaptured
individuals in each grid 24 hours after release, July 9, 1985.
(Grids are one m²)

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# FCD SITE
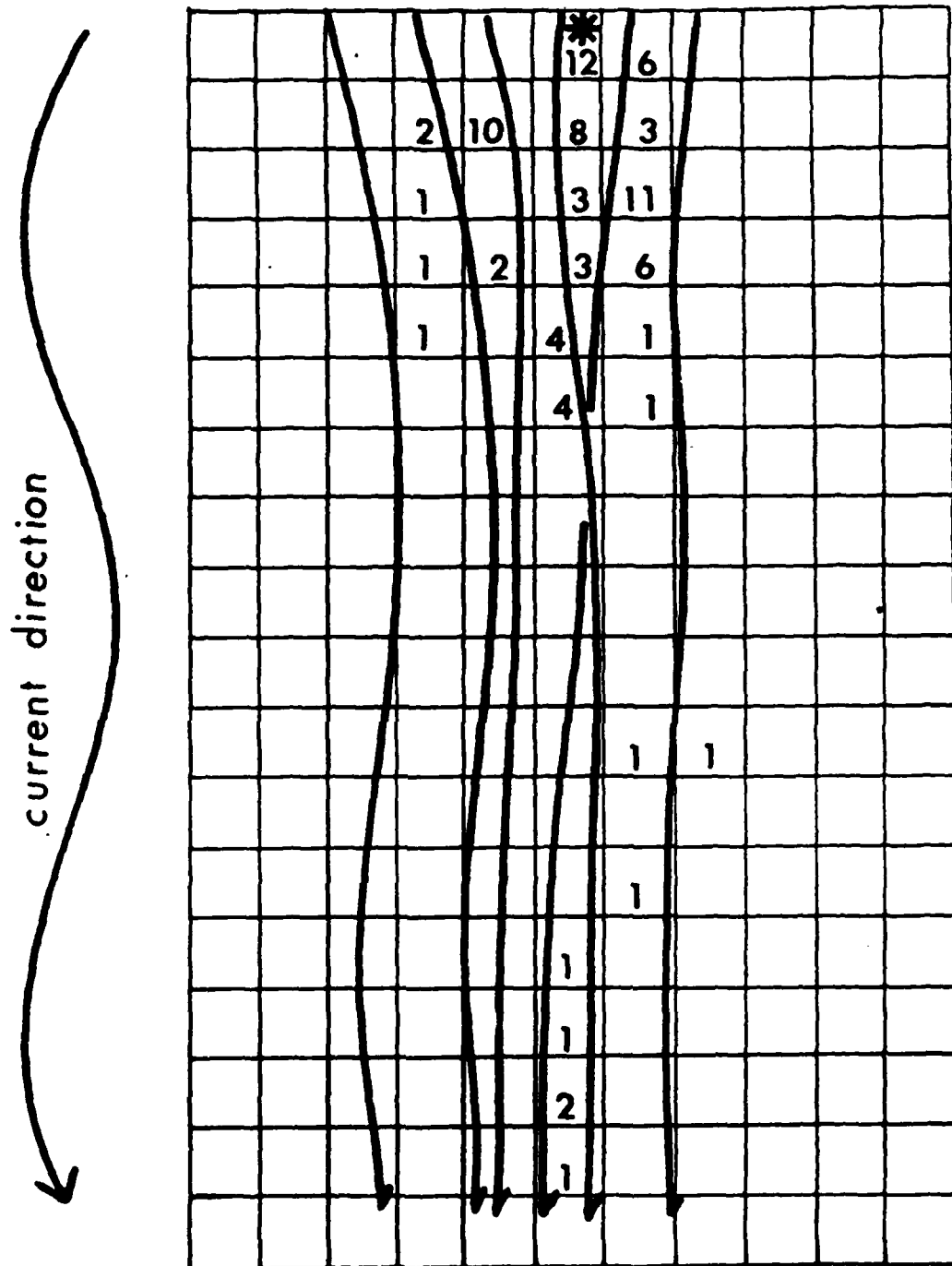


**FIGURE 5.2**

Mark-recapture site at FCD. Curved lines depict flow patterns. Asterisk represents release site. Values are numbers of recaptured individuals in each grid 24 hours after release, July 16, 1985. (Grids are one m$^2$)

coarse sand was higher at FEX than at FCD (FEX = 90%, FCD = 60%). In spite of these physical differences, mark-recapture results between the two sites were similar.

Mark-Recapture Results.-- Naiads of O. colubrinus (during the experiment) were rather sessile. The net movement direction was downstream, and the marked animals were recaptured along the current flows below the release site. Figures 5.1 and 5.2 show the current flow pattern, along with numbers of marked animals found in each meter square grid. Figure 5.1 are data from the 24 hr recapture in July at FEX and Figure 5.2 shows data for the same time period at FCD. Not only was the pattern of recovery similar to flow patterns, but the distances travelled downstream were relatively short. Table 5.1 and figures 5.3 and 5.4 show that over 70% of recaptured individuals, after 24 hr, were taken within 6 m of the release site, with one notable exception. Between 9 and 10 August, a heavy rain-storm occurred, causing water depth at the FCD ambient monitoring station to increase by 10 cm. Although percent recapture success on 10 August at FCD was not low (Table 5.1), recapture distances were longer (Fig. 5.4). Over 14 m distance was necessary before 70% of the marked animals were recovered. Similar rains did not occurr for any of the other mark-recapture series.

TABLE 5.1
Mark-Recapture Results for O. colubrinus

| DESCRIPTION | FEX, July 8 - 11 | | | FCD, July 15 - 18 | | |
| | 24 hr | 48 hr | 72 hr | 24 hr | 48 hr | 72 hr |
| --- | --- | --- | --- | --- | --- | --- |
| % Recapture Success | 31.45 | 30.92 | 22.17 | 33.85 | 27.20 | 6.47 |
| Mean Distance Moved | 5 meters | | | 5 meters | | |
| Lincoln Index Values over No. Square M. | $248/78 = X/317$ over 25 | | | $257/87 = X/364$ over 25 | | |
| Population Size Per Square M. | 40.3 | | | 43.0 | | |

| | FEX, Aug. 2 | FCD, Aug. 10 |
| | 24 hr | 24 hr |
| --- | --- | --- |
| % Recapture Success | 40.45 | 28.08 |
| Mean Distance | 5 meters | 8 meters |

**FEX, JULY vs. AUG., 24H PERIOD**
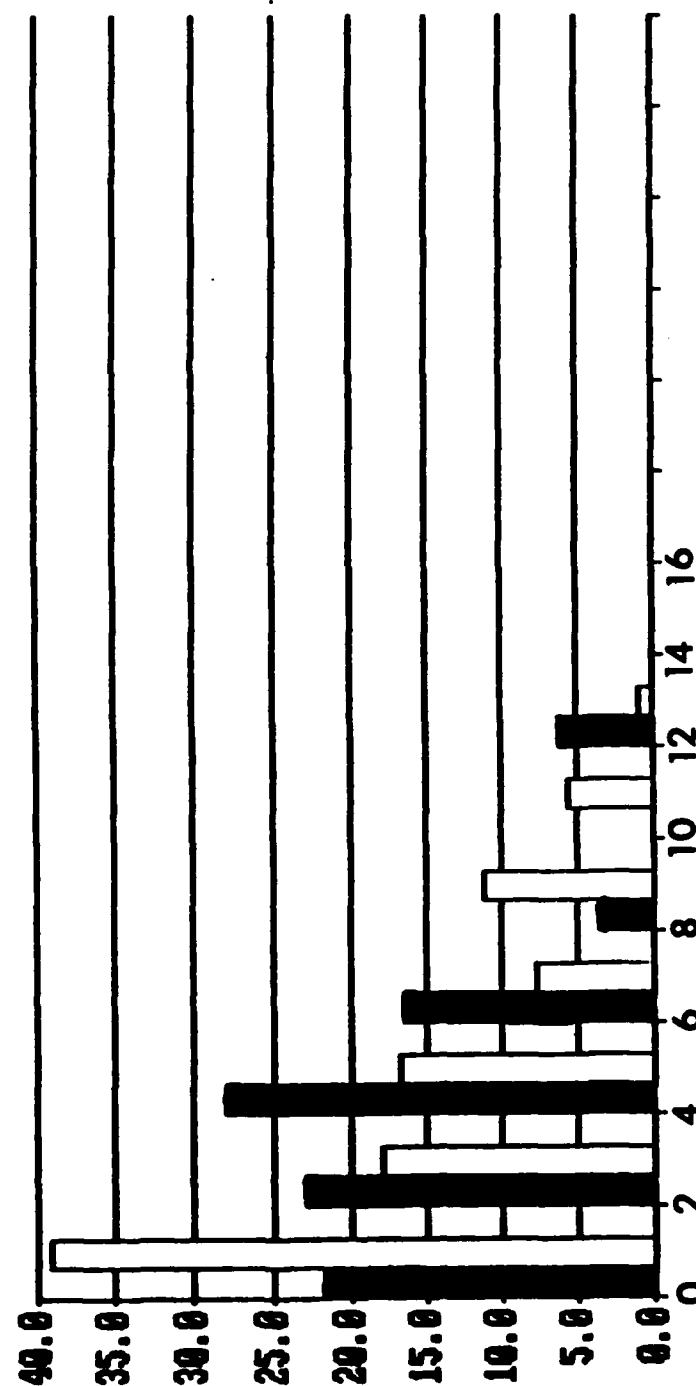
FIGURE 5.3

Cumulative percent of recaptured animals from FEX release site after 24 hours, July and August, 1985
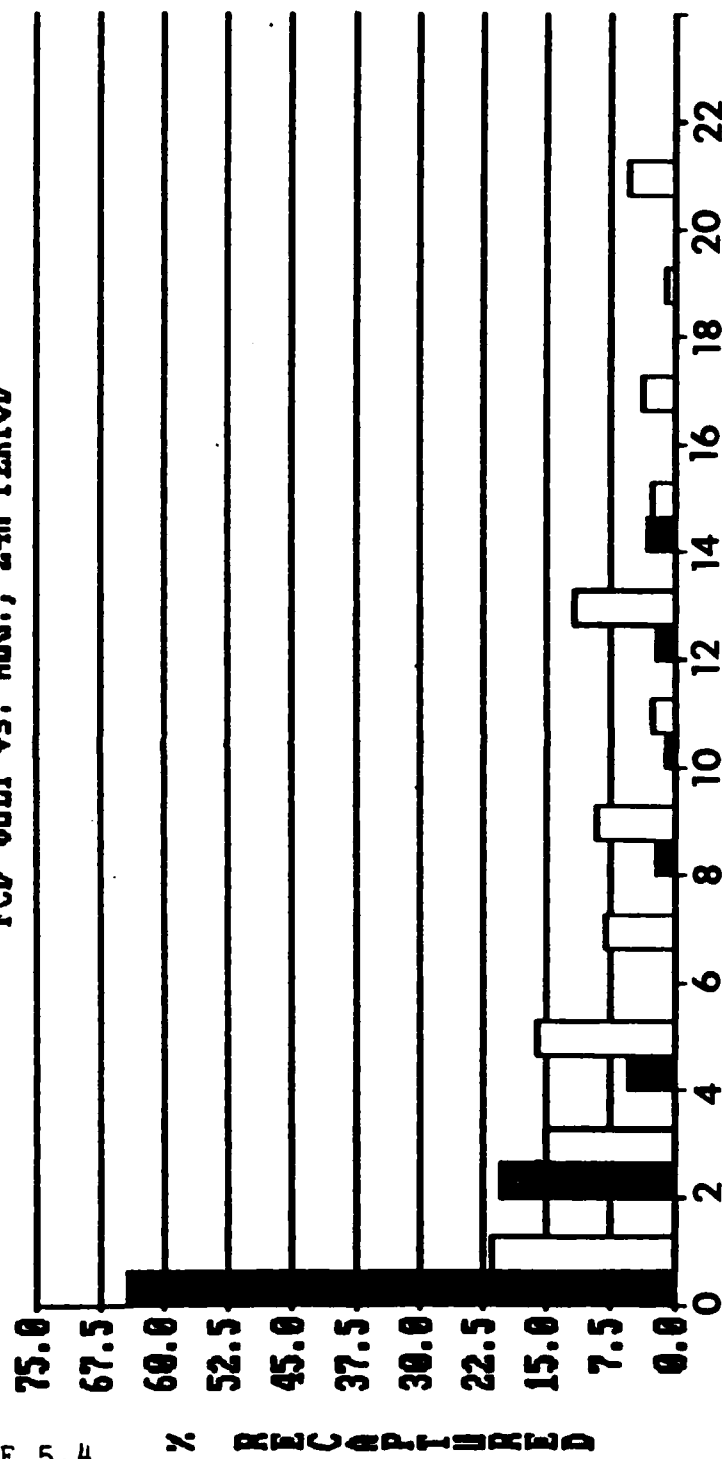
100

FIGURE 5.4

Cumulative percent of recaptured animals from FCD release site after 24 hours, July and August, 1985.

TABLE 5.1, continued

----------------------------------------------------------------------

|  | FEX, Aug 2<br>24 hr | FCD, Aug 10<br>24 hr |
|---|---|---|

----------------------------------------------------------------------

| Lincoln Index<br>Values over<br>Square M. | 220/89 = X/143<br>———————<br>22 | 260/73 = X/321<br>———————<br>28 |
| Population Size<br>Per Square M. | 15.4 | 40.8 |

---

The rather sessile animals were never recaptured above the release sites in July or August. At least for the period of the study, the animals moved short distances, unless they were lifted from the stream bottom by other predators, researchers or floods. Our replacement of marked individuals certainly was difficult, owing to the animals' propensities to flow with the current until they passively encountered an obstacle. Only then would they actively move away from the direct current flow. Our field observations were compatible with locations of marked individuals relative to current flow patterns (Compare figs. 5.1, 5.2 with Table 5.1).

Tables 5.1 and 5.2 give the overall percent recapture success as well as population estimates for both sites. Recapture success was always over 20% with one exception (72 hr at FCD). Because we do not assume that marked animals randomly assorted themselves among the rest of the unmarked population, our estimates of population size are open to some question. Estimates were computed using only grids that included marked animals. We used the Lincoln Index Method. In 1984, population densities were determined at both sites by a direct count method (Table 5.2). (Individuals were counted from one meter square substrate samples). These population estimates were similar to the ones obtained by mark-recapture methods (Table 5.1) except for FEX in August. Very few unmarked animals were collected at that time (143 versus 317 in July). Either the kickscreen method differentially affected the population at FEX in August, or the population size had significantly diminished there prior to August. Further, the mean distance moved after 24 hr in August at FCD was farther (8 vs. 5 meters) than at any other time. We suspect that the rains that fell between the time we marked the animals and when we recaptured them contributed significantly to lower recapture success and mean longer distances that the marked animals traveled (see Table 5.1).

## TABLE 5.2
### Population Estimates of O. colubrinus, Based on Direct Counts (No./Square M.)

| | SITES AND DATES | | | | | |
| | FEX | | | FCD | | |
| | 12 July | 26 July | 23 Aug | 11 July | 25 July | 22 Aug |
|---|---|---|---|---|---|---|
| mean | 47.3 | 47.6 | 48.6 | 73.3 | 50.9 | 71.4 |
| s.d. | 25.3 | 14.0 | 15.9 | 28.9 | 31.7 | 43.3 |
| sample no. | 7 | 7 | 7 | 7 | 7 | 7 |

After 48 and 72 hr, percent recapture success was lower (Table 5.1) and distances travelled were longer for the most part (Fig. 5.5) as compared with results after 24 hr (Table 5.1; figs. 5.3, 5.4). Given the higher reliability of recapture success and distances travelled after 24 and 48 hr, we plan on not recapturing animals after 72 hr for the 1986 season.

## Discussion

1985 Studies.--This dragonfly predator, in searching prey, appears to travel short distances -- at least during summer months. Owing to its rather sessile habits, high recapture success is possible. Also, movement patterns can be determined with good reliability. On the other hand, one assumption for population estimates based on mark-recapture studies cannot be met: We cannot assume that marked animals resort themselves randomly in the population after release. Rather, they appear to respond to current flow patterns more than to the substrate itself. Thus, population estimates are subject to question. We chose to base population estimates using grids that included marked animals. Bias owing to nonrandom reassortment were hopefully minimized by excluding grids without marked animals.

The most powerful results from this element are those showing distances travelled over time rather than population estimates. If ELF effects alter movements of these animals such that they travel significantly longer distances, we should be able to detect differences if we repeat mark-recapture studies under similar physical and temporal conditions. Because gathering the necessary data is labor intensive, and other elements must be considered as well, we plan to repeat the 24 and 48 hr studies at both sites only twice during each field season.

**O. COLUBRINUS, FEX (July,1985)**

METERS DOWNSTREAM FROM RELEASE ➡
■fex,24hr ☐fex,48hr ⊟fex,72hr
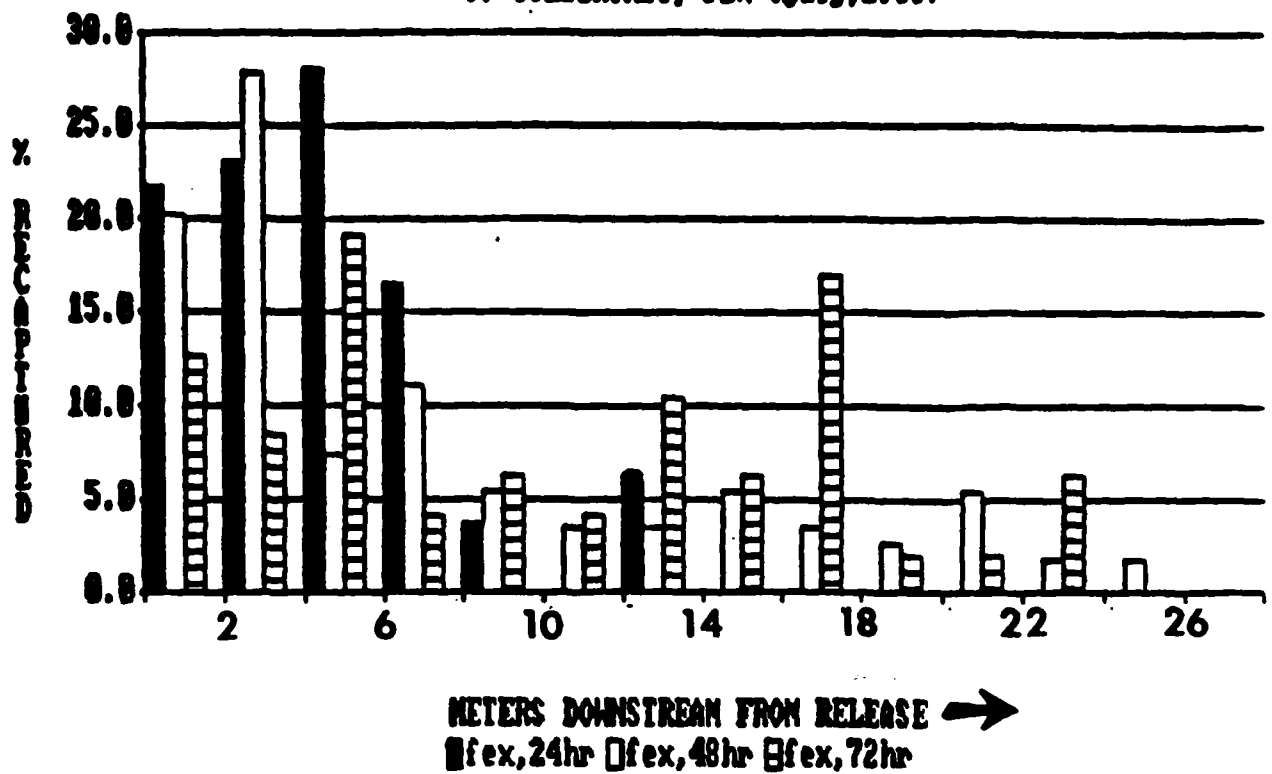
**O. COLUBRINUS, FCD (july,1985)**

METERS DOWNSTREAM FROM RELEASE ➡
■fcd,24hr ☐fcd,48hr ⊟fcd,72hr
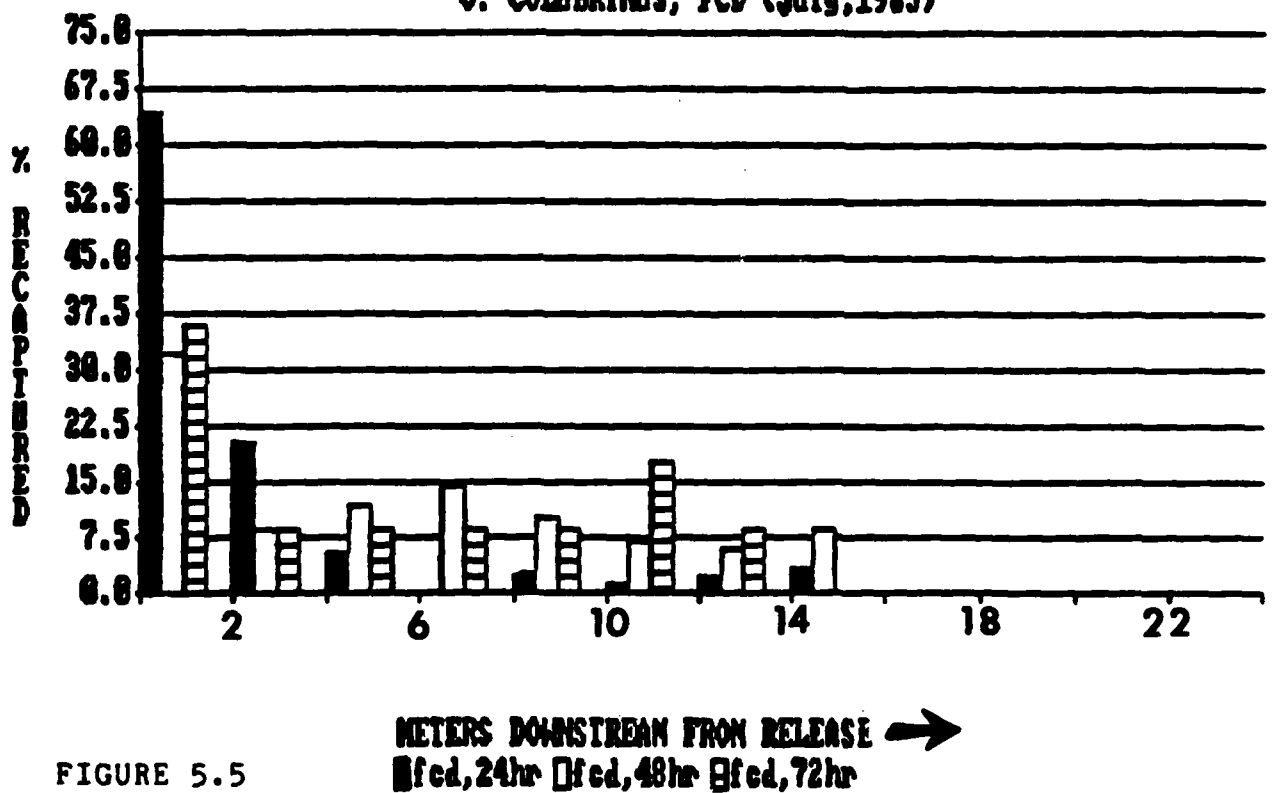
FIGURE 5.5

Cumulative percent of recaptured animals from FEX and FCD 24, 48, and 72 hours after release, July, 1985.

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Comparison With 1984 Studies.-- Although percent recapture sucess was lower in 1985 than in 1984, the success rates for both years were very high, relative to most mark-recapture aquatic invertebrate studies (Stout, 1978, 1981, Bovbjerg, 1952). The direction of movement for these animals over the two years was the same: downstream. The distances travelled were also similar (Compare present results with Fig. 5.2 of the 1984 Annual Report.). In 1984, the maximum distance after 24 hr at FEX was 10 m and after 96 hr it was 7 m. At FEX in 1985, the maximum distance after 24 hr was 14 m, after 48 hr was 26 m, and after 72 hr was 24 m. We added population estimates as well as FCD mark-recapture studies in 1985, and thus, cannot compare those results with 1984. However, separate studies in 1984 by David Cornelius, a graduate student on the project, were used for comparison with our population estimates in 1985.

(In 1984 we stated that we were going to add another insect to the study: The stonefly, Acroneuria. We found, in 1985, that the abundances were too low for mark-recapture studies.)

Summary

Naiads of O. colubrinus travelled in a downstream direction for brief distances at both sites. In 1984, only FEX was studied. Those results are in agreement with results obtained at the site as well as at FCD in 1985. Percent recapture success is high (30 to 50%) making us rather confident that the data reflect the actual movement patterns of this predator. Finally, owing to their numerical dominance, "markability", and sessile behavior, these animals are very appropriate animals by which movement patterns can be monitored in the event that ELF affects movement patterns of this, possibly sit-and-wait, dragonfly predator.

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Bovbjerg, R. V., 1952. Ecological aspects of dispersal of the snail Campeloma decism. Ecology, 33:169-176.

Southwood, T. R. E., 1966. Ecological methods. Methuen & Co., Ltd., London. 391 pp.

Stout, R. J., 1978. Migration of the aquatic hemipteran Limnocoris insularis (Naucoridae) in a tropical lowland stream (Costa Rica, Central America). Brenesia, 14:1-11.

Stout, R. J., 1981. How abiotic factors affect the distribution of two species of tropical predaceous aquatic bugs. Ecology, 62:1170-1178.

## Element 6 - Leaf Litter Processing

Changes from the Original Synopsis   - None.

## Objectives

1.  To monitor fresh-summer and autumn-abscissed leaf processing rates;  2) to monitor colonization patterns of insects on leaves of two physiological states (fresh and autumn), 3) to compare results from the 1984 study with those from the 1982-83 study, and 4) to compare leaf degradation rates for 1982-83, 1984 and 1985.. Insect colonization patterns on the leaves for 1985 will be presented in the next Annual Report, as the last collection date occurs in mid-December, 1985.  (Insect identifications and data entry require at least two months.)

Processing rates of leaves incorporate the functional responses of fungi, bacteria, other micro-organisms and certain aquatic insects as they use leaves as both a nutritive and substrata resource.  If E.L.F. alters any of those communities, differences in processing rates of the leaves themselves should be expected.  As data thus far show that fresh summer and autumn senescent leaves have predictable and consistent leaf processing rates, rate changes as a function of E.L.F. should be detected.

Insects colonize leaves in a general sequential pattern:  After conditioning by bacteria and fungi, insect functional feeding groups such as shredders, scrapers, collector-gatherers, filter-feeders and predators arrive in sequence.  If any of those sequence "groups" is missing as a function of E.L.F., not only the sequence pattern, but relative abundances and growth rates of insects on leaves over time can be altered.  Changes would be detected via changes in numbers and/or biomasses of functional feeding groups as well as size class structural alterations. As shredders are often the first insects to arrive, it is expected that they may be the most susceptable to prior deviations in the micro-organism community.  Thus, particular attention to shredders is given in the event this is the case. Also, changes in leaf processing rates may be related to changes in insect functional feeding groups.  Both will be monitored simultaneously.

## 1984 Data

## Materials and Methods

On September 19, 1984, freshly picked Tag Alder (Alnus rugosa) leaves  were put into leaf packs of 10 leaves per pack, lashed to bricks and placed in the Ford River at the

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FEX and FCD sites. The previous year's autumn leaves were
placed there also on 19 September after they had been dried
at 60oC for 48 hr and weighed into approximately 3g leaf
packs (10-12 leaves per pack). Five replicates per leaf
treatment were collected after 3, 10, 24, 54 and 91 days.
Leaves were washed over a 60µm mesh sieve and insects were
stored in 70% ethanol. Washed leaves were dried at 60oC for
48 hr and then weighed to nearest mg.

Leaf processing rates (-k) were computed after Petersen
and Cummins, 1975. Two-Way ANOVA tests (site versus
treatment; changes in -k over time) were run after tests
for homogeneity of variances.

After the insect taxa were determined, insects were
measured to the nearest mm for later computation of biomass
values. Species diversity (H'), richness (S) and evenness
(J') were computed for each replicate. Number of
individuals and total biomass for each replicate were also
computed. For select taxa, percent numerical dominance
and/or mean biomass per individual were determined.
Finally, total biomass values for functional feeding group
categories (including a special category, Chironomidae) were
computed (after Merritt and Cummins, 1984). Coefficient of
variation (C.V.) values for each estimated parameter from each
set of replicates were computed. A power test was used to
determine if sufficient replicates had been collected to
have, 95% of the time, confidence that the mean varied no
more than $\pm$ 40% with an alpha of .05. (Five replicates were
sufficient if the parameter had a CV value of 18% or less.)
If values for any parameter were not normally distributed,      ·
they were transformed prior to analysis (e.g., percent data).

## Results and Discussion

Leaf Processing Rates.-- Figure 6.1 shows that fresh
summer leaves were processed significantly faster than were
autumn-abscissed leaves at each site (Two-Way ANOVA for FEX:
$F(1,39) = 15.86$, p $<.0004$; for FCD: $F(1,39) = 5.093$, p
$= .03$). Autumn-abscissed leaves showed no difference in
processing rates between the two sites (Two-Way ANOVA: $F(1,39)$
$= 0.892$, p $= 0.352$). Fresh summer leaves were processed
significantly faster at FEX than at FCD (Two-Way ANOVA:
$F(1,39) = 14.999$, p $<.0001$). Because the interaction term
(time) for the above analysis was significant for fresh leaf
loss at the two sites, collection dates were analyzed separ-
ately for site vs. treatment comparisons (see Table 6.1).
After Day 10, treatment differences (fresh versus autumn
leaves) were significant but site differences were not
significant.

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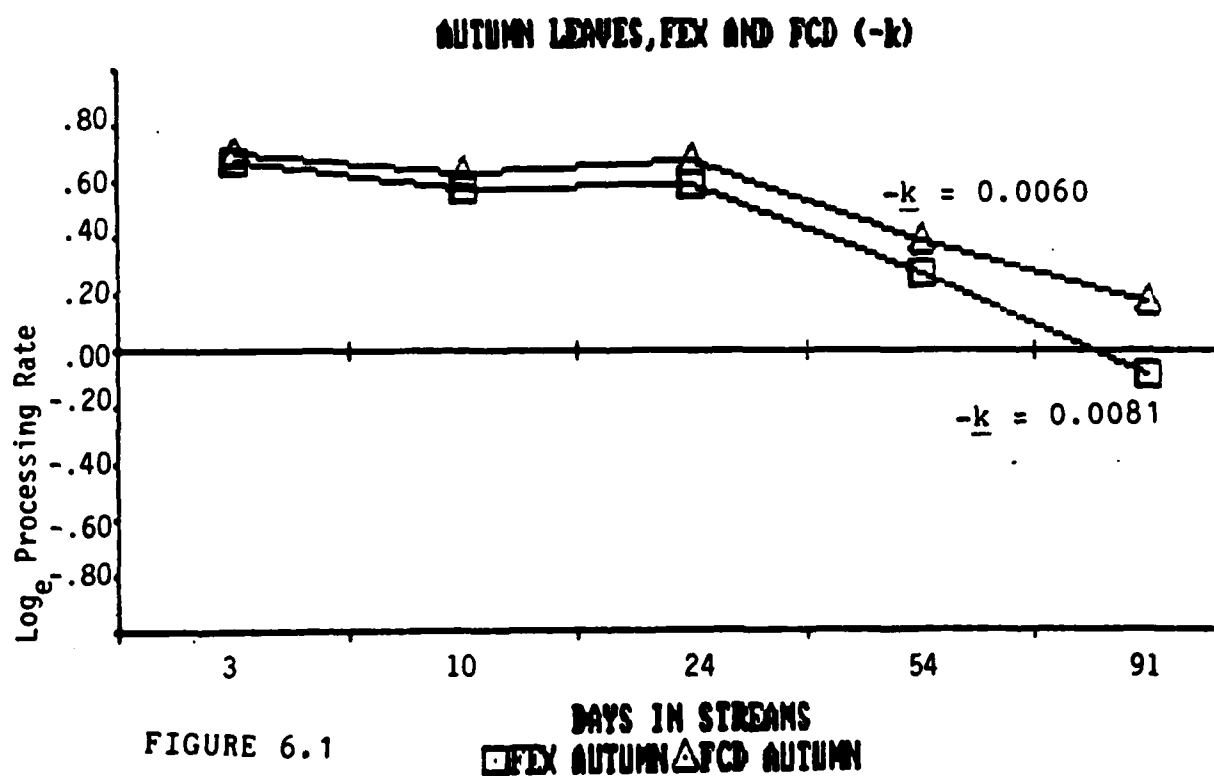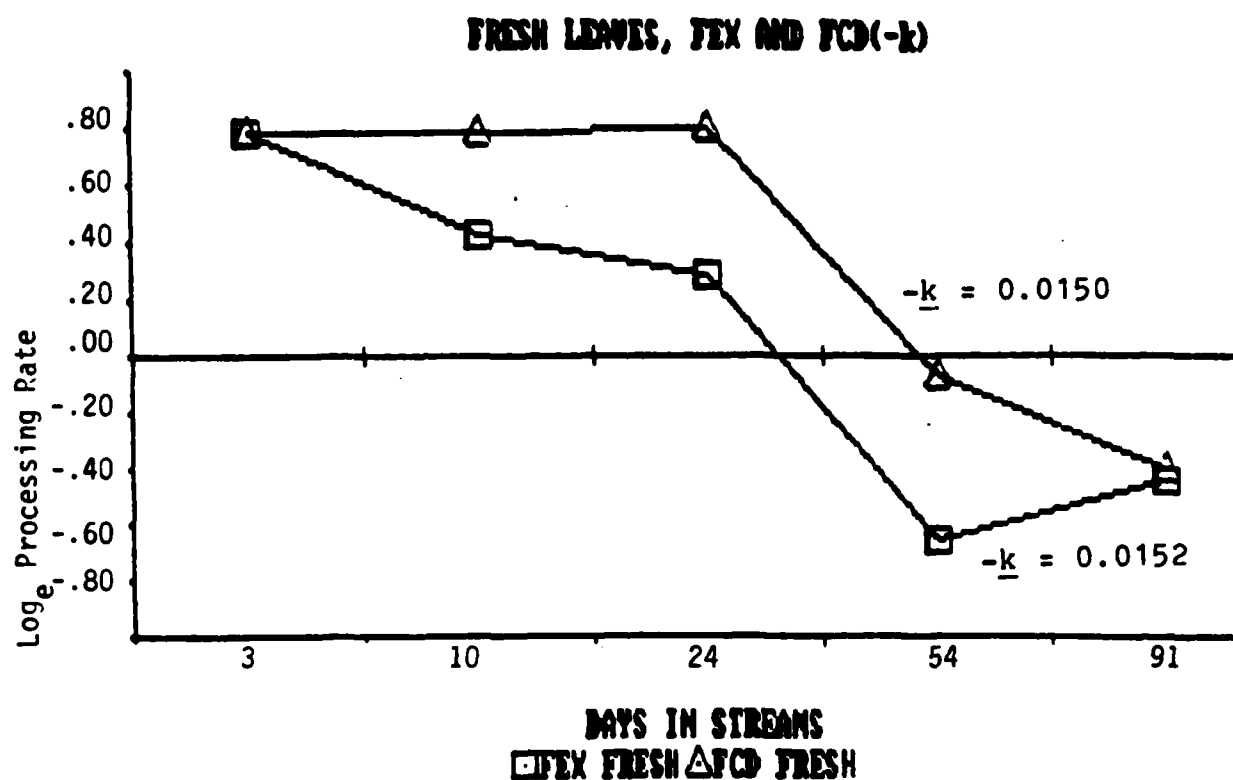
FIGURE 6.1

Processing rates of fresh and autumn leaves at FEX and FCD over time (September 19 - December 27, 1984).

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TABLE 6.1
Comparisons of Fresh and Autumn Leaf Losses at FEX and FCD
Two-Way ANOVA for Site Versus Treatment

| Days in Stream | Source | d.f. | MSS | F-ratio | Prob. |
|---|---|---|---|---|---|
| 3 | site | 1 | .007 | .396 | .541 |
| | treatment | 1 | .006 | .305 | .591 |
| | interaction | 1 | .001 | .053 | .800 |
| | error | 16 | .019 | | |
| 10 | site | 1 | .188 | 8.695 | .012** |
| | treatment | 1 | .0001 | .009 | .927 |
| | interaction | 1 | .082 | 3.727 | .0776 |
| | error | 16 | .022 | | |
| 24 | site | 1 | .106 | 1.070 | .322 |
| | treatment | 1 | .535 | 5.352 | .040** |
| | interaction | 1 | .328 | 3.313 | .094 |
| | error | 16 | .099 | | |
| 54 | site | 1 | .095 | 1.312 | .274 |
| | treatment | 1 | 1.374 | 19.030 | .0009*** |
| | interaction | 1 | .020 | .278 | .608 |
| | error | 16 | .072 | | |
| 91 | site | 1 | .012 | .094 | .765 |
| | treatment | 1 | .824 | 6.728 | .024** |
| | interaction | 1 | .083 | .680 | .427 |
| | error | 16 | .122 | | |

Insects Colonizing Leafpacks.--

Structural Community Parameters: Taxon diversity
values began to stabilize by Day 10 and then decrease after
Day 24 for fresh and autumn leaves (Fig. 6.2). Two-Way
ANOVA tests for each collection date showed that site (FEX
vs. FCD) but not treatment (fresh vs. autumn) differences
were significant for two dates (days 3 and 54, Table 6.2).
Coefficient of variation (CV) values were all well below 18%
except for Day 91 where fresh and autumn leaves were 20.25
and 19.36%, respectively at FCD. This is reflected in the
error term at Day 91 (Table 6.2).
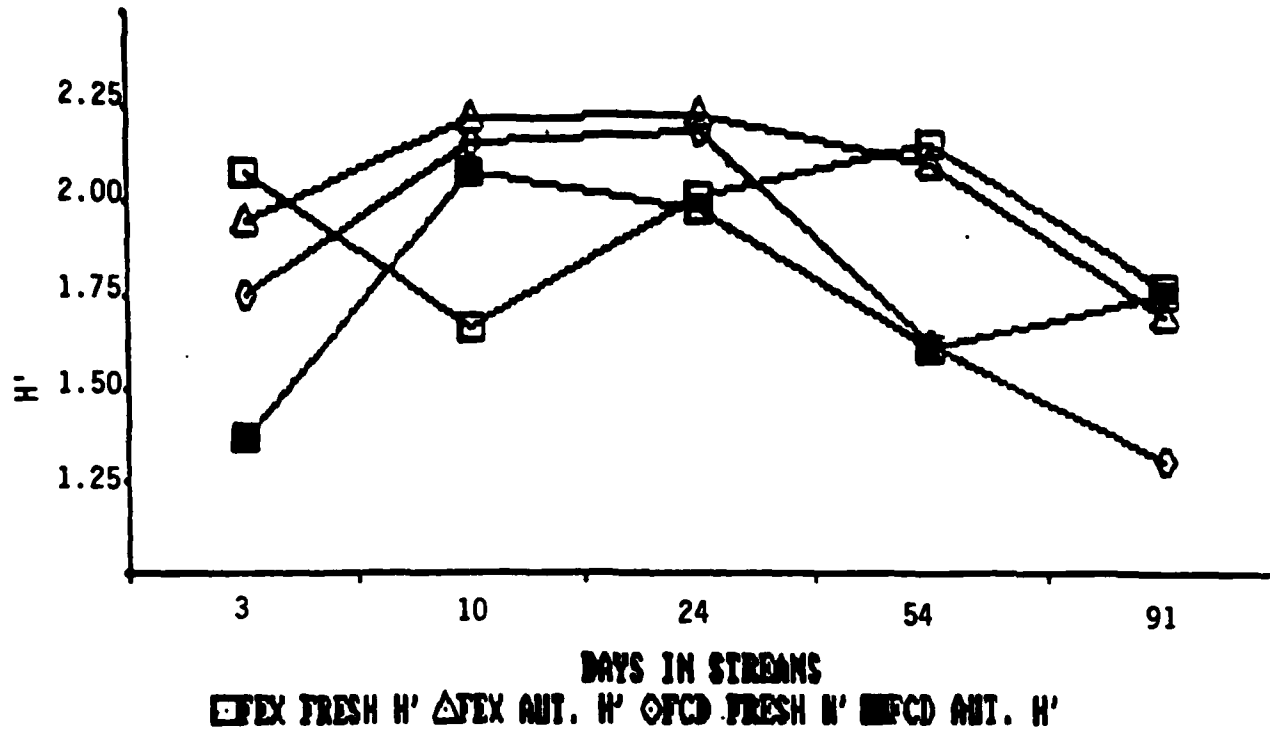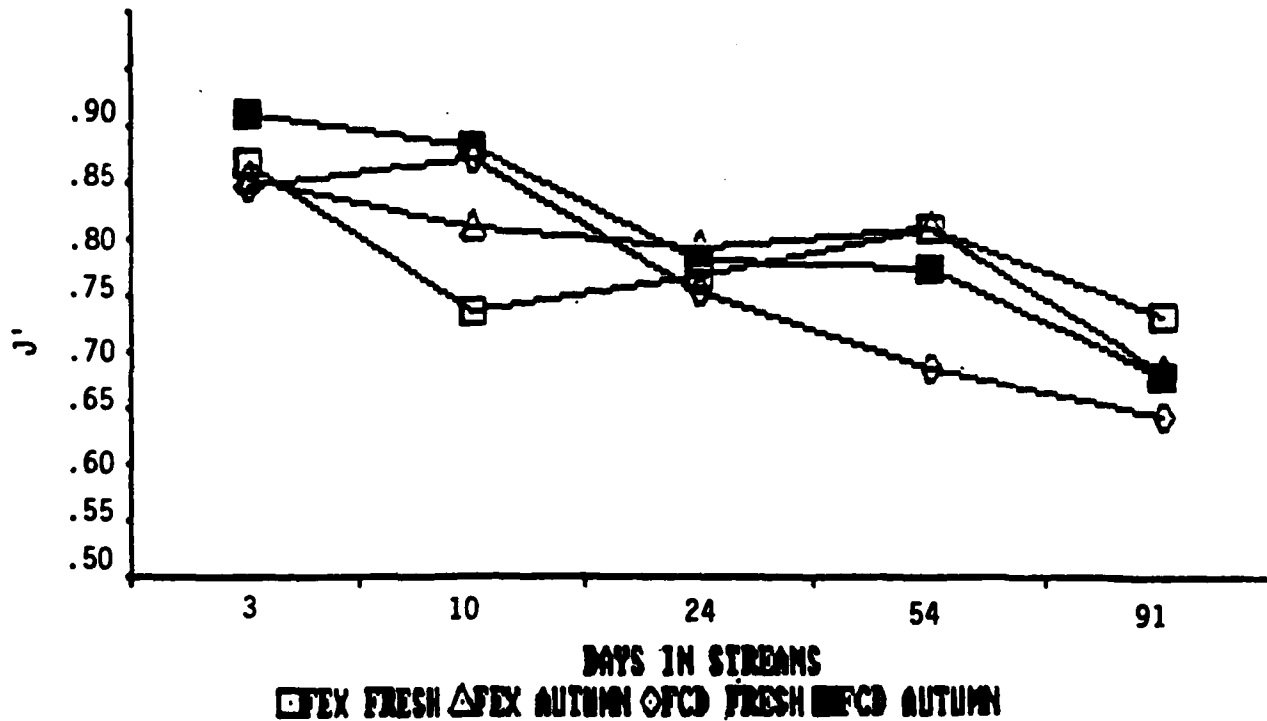
FIGURE 6.2
                diversity (H') and species evenness (J') values for insects
on fresh and autumn leaves at FEX and FCD (September 19 - December 27,
1984)

## TABLE 6.2
Comparison of Taxon Diversity Values for Insects on
Fresh and Autumn Leaves at FEX and FCD
Two-Way ANOVA for Site Versus Treatment Differences

| Days in Stream | Source | d.f. | MSS | F-ratio | Prob. |
|---|---|---|---|---|---|
| 3 | site | 1 | .990 | 11.299 | .004*** |
| | treatment | 1 | .325 | 3.715 | .072 |
| | interaction | 1 | .082 | .932 | .349 |
| | error | 16 | .088 | | |
| 10 | site | 1 | .155 | 1.413 | .252 |
| | treatment | 1 | .261 | 2.374 | .143 |
| | interaction | 1 | .490 | 4.454 | .051 |
| | error | 16 | .110 | | |
| 24 | site | 1 | .009 | .137 | .716 |
| | treatment | 1 | .001 | .018 | .894 |
| | interaction | 1 | .006 | .095 | .759 |
| | error | 16 | .063 | | |
| 54 | site | 1 | 1.329 | 16.002 | .001*** |
| | treatment | 1 | .055 | .666 | .426 |
| | interaction | 1 | .0001 | .001 | .988 |
| | error | 16 | .083 | | |
| 91 | site | 1 | .210 | 1.406 | .253 |
| | treatment | 1 | .166 | 1.113 | .307 |
| | interaction | 1 | .337 | 2.262 | .152 |
| | error | 16 | .149 | | |

Evenness values (J') lowered with time (Fig. 6.2).
Only on Day 10 were there site differences (Table 6.3). At
that time, both fresh and autumn leaf J' values were lower
at FCD. CV values were above 18% only for autumn leaves at
FCD on Day 54; thus, for the most part, sufficient samples
had been taken to reduce the probability of a Type II error.

## TABLE 6.3
Comparisons Among Evenness (J') Values (arcsin transform)
for Insects on Fresh and Autumn Leaves at FEX and FCD
Two-Way ANOVA for Site Versus Treatment Differences

| Days in Stream | Source | d.f. | MSS | F-ratio | Prob. |
|---|---|---|---|---|---|
| 3 | site | 1 | 36.91 | 1.446 | .247 |
| | treatment | 1 | 57.97 | 2.271 | .151 |
| | interaction | 1 | 116.307 | 4.557 | .049** |
| | error | 16 | 25.525 | | |

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TABLE 6.3 continued...

| Days in | Source | d.f. | MSS | F-ratio | Prob. |
|---|---|---|---|---|---|
| 10 | site | 1 | 601.266 | 16.305 | .001*** |
|  | treatment | 1 | 98.479 | 2.671 | .122 |
|  | interaction | 1 | 29.330 | .795 | .386 |
|  | error | 16 | 36.875 |  |  |
| 24 | site | 1 | 5.544 | .621 | .442 |
|  | treatment | 1 | 30.876 | 3.459 | .081 |
|  | interaction | 1 | .146 | .016 | .900 |
|  | error | 16 | 8.926 |  |  |
| 54 | site | 1 | 193.750 | 2.730 | .118 |
|  | treatment | 1 | 107.420 | 1.514 | .236 |
|  | interaction | 1 | 114.100 | 1.427 | .223 |
|  | error | 16 | 70.960 |  |  |
| 91 | site | 1 | 70.425 | 2.045 | .172 |
|  | treatment | 1 | .003 | .001 | .930 |
|  | interaction | 1 | 59.616 | 1.731 | .207 |
|  | error | 16 | 34.44 |  |  |

Taxon Richness (S) values tended to increase with time (Fig. 6.3). There were site and treatment differences at Day 3 and at Day 54 (Table 6.4). This occurred when S for autumn leaves at FCD fell way below S values for FEX fresh and autumn leaves (Fig. 6.3). C.V. values were below 18% except for fresh leaves on Day 10 at both sites and fresh leaves at FEX on Day 91 (See error terms in Table 6.4).

TABLE 6.4
Comparisons Among Taxon Richness Values (S) for Insects
on Fresh and Autumn Leaves at FEX and FCD
Two-Way ANOVA for Site Versus Treatment Differences

| Days in Stream | Source | d.f. | MSS | F-ratio | Prob. |
|---|---|---|---|---|---|
| 3 | site | 1 | 48.050 | 11.791 | .003*** |
|  | treatment | 1 | 31.250 | 7.669 | .014** |
|  | interaction | 1 | 11.250 | 2.761 | .116 |
|  | error | 16 | 4.075 |  |  |
| 10 | site | 1 | 22.050 | 2.227 | .115 |
|  | treatment | 1 | 1.250 | .126 | .727 |
|  | interaction | 1 | 22.050 | 2.227 | .155 |
|  | error | 16 | 9.900 |  |  |
| 24 | site | 1 | .200 | .050 | .825 |
|  | treatment | 1 | 16.200 | 4.075 | .061 |
|  | interaction | 1 | 51.200 | 12.864 | .002*** |
|  | error | 16 | 3.980 |  |  |

MEAN NO. SPECIES AT FEX, FCD

DAYS IN STREAMS

□fex fresh △fex autumn ◇ fcd fresh■ fcd autumn

MEAN NO. INDIVIDUALS AT FEX, FCD

DAYS IN STREAMS
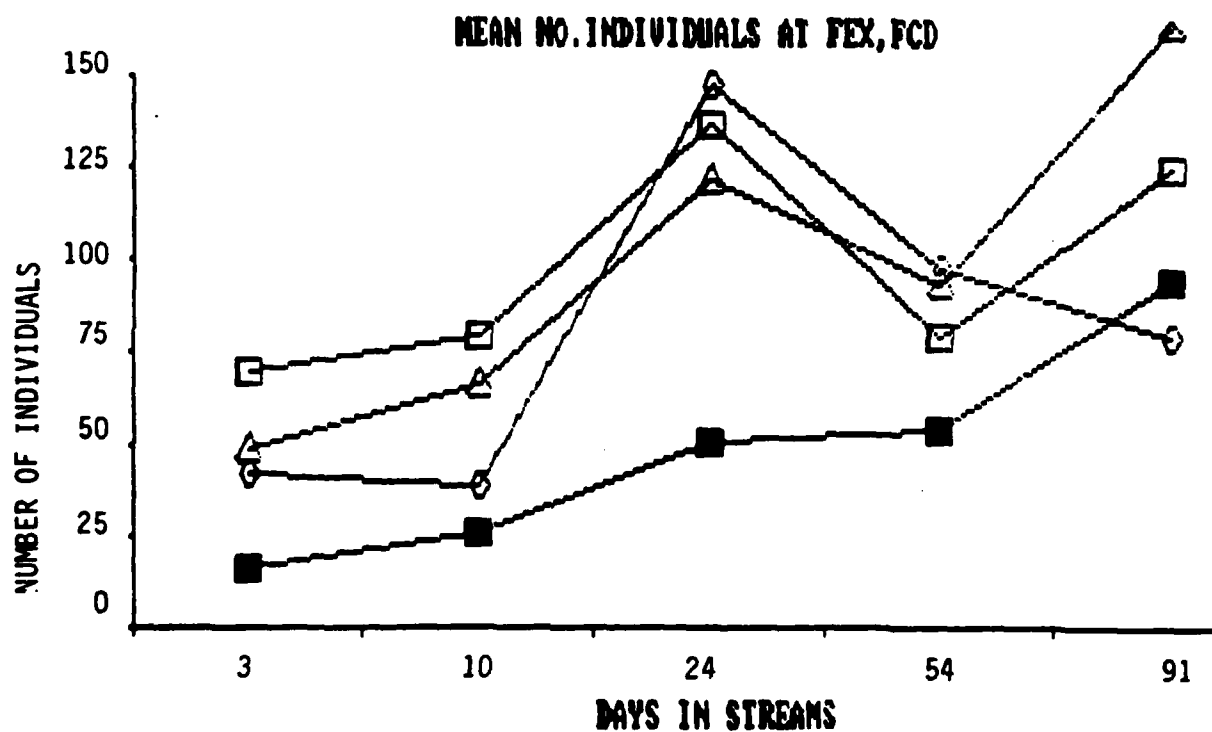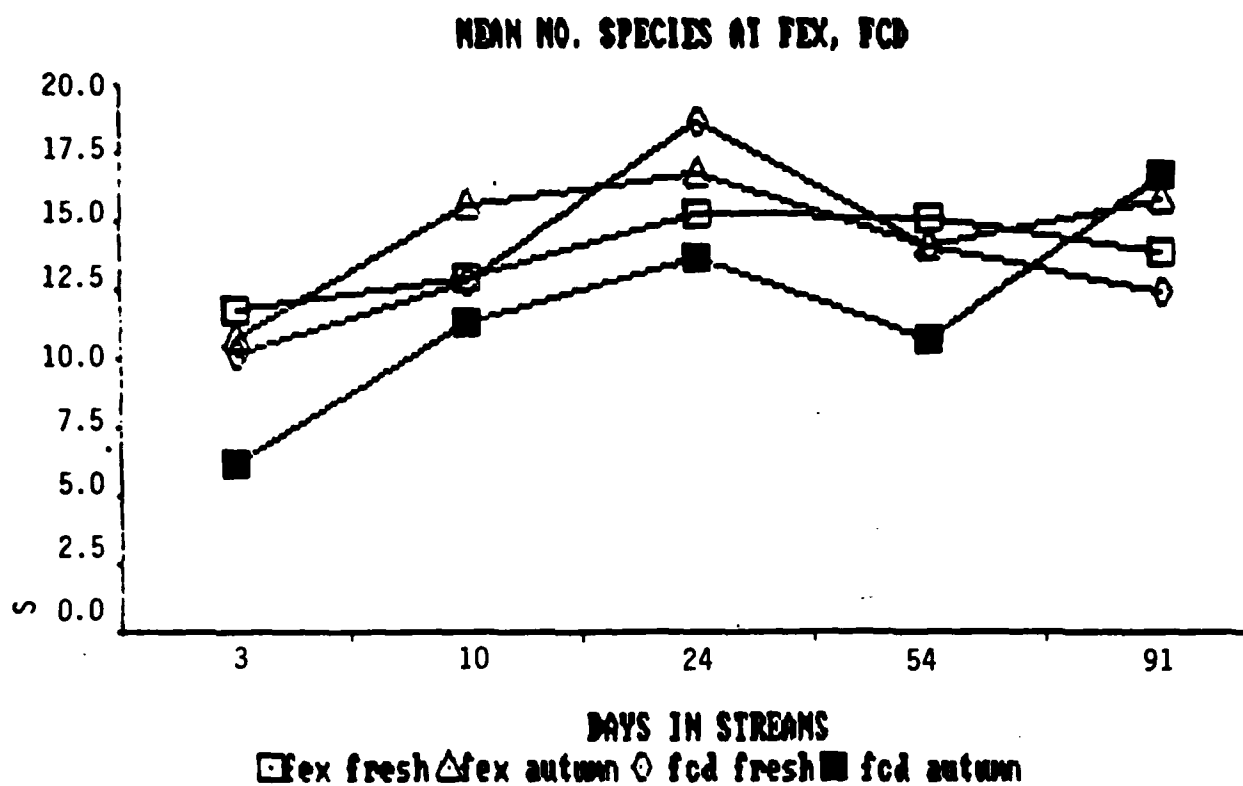
FIGURE 6.3 □fex fresh △fex autumn ◇ fcd fresh■ fcd autumn

Species richness (S) and mean number of individuals on fresh and autumn leaves at FEX and FCD (September 19, 1984 to December 27, 1984)

TABLE 6.4 continued...

| Days in | Source | d.f. | MSS | F-ratio | Prob. |
|---|---|---|---|---|---|
| 54 | site | 1 | 24.200 | 5.149 | .037** |
| | treatment | 1 | 24.200 | 5.149 | .037** |
| | interaction | 1 | 7.200 | 1.532 | .234 |
| | error | 16 | 4.700 | | |
| 91 | site | 1 | .450 | .039 | .846 |
| | treatment | 1 | 48.050 | 4.133 | .059 |
| | interaction | 1 | 6.050 | .520 | .481 |
| | error | 16 | 11.625 | | |

Numbers of individuals, as with S', tended to increase with time (Fig. 6.3). All except autumn leaves at FCD also showed a definite peak at Day 24. There were significantly more individuals on each leaf treatment at FEX than at FCD on Day 10 and 91 (Table 6.5). Treatment differences were significant only on Day 24; numbers of individuals were lower on autumn leaves at FCD. C.V. values were all over 18% (approximately 40%). Much higher numbers of replicates for this parameter would have to have been taken to have a 95% confidence that the mean was $\pm$ 40% of its estimated value at the alpha .05 level.

TABLE 6.5

Comparisons Among Numbers of Individuals on Fresh and Autumn Leaves at FEX and FCD
Two-Way ANOVA for Site Versus Treatment Differences

| Days in | Source | d.f. | MSS | F-ratio | Prob. |
|---|---|---|---|---|---|
| 3 | site | 1 | 4651.250 | 18.557 | .0005*** |
| | treatment | 1 | 2802.450 | 11.205 | .004*** |
| | interaction | 1 | 26.450 | .106 | .750 |
| | error | 16 | 250.650 | | |
| 10 | site | 1 | 8000.000 | 16.107 | .001*** |
| | treatment | 1 | 819.200 | 1.649 | .217 |
| | interaction | 1 | .200 | .0004 | .984 |
| | error | 16 | 496.750 | | |
| 24 | site | 1 | 897.800 | .991 | .334 |
| | treatment | 1 | 7449.800 | 8.226 | .011** |
| | interaction | 1 | 2737.800 | 3.023 | .101 |
| | error | 16 | 905.675 | | |
| 54 | site | 1 | 2000.000 | 1.278 | .275 |
| | treatment | 1 | 96.800 | .062 | .807 |
| | interaction | 1 | 7527.200 | 4.809 | .043** |
| | error | 16 | 1565.200 | | |

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TABLE 6.5 continued...

| Days in | Source | d.f. | MSS | F-ratio | Prob. |
|---|---|---|---|---|---|
| 91 | site | 1 | 16646.450 | 7.478 | .015** |
| | treatment | 1 | 3726.450 | 1.674 | .214 |
| | interaction | 1 | 732.050 | .329 | .574 |
| | error | 16 | 2225.925 | | |

The temporal increase in S and in numbers of individ-
uals, contrasted with the consistent decrease in J' and a
reduction in H' after Day 24 is attributed to a constant
increase in percent numerical dominance of chironomids over
time (Fig. 6.4). Between Day 3 and Day 91, percent domi-
nance went from about 15% to over 50%.

Functional Community Parameters: Total biomass values,
in spite of high variance values inherent in this parameter,
showed a consistent upward trend over time (figs. 6.5 -
6.6). Although fresh leaves supported more insect biomass
than autumn leaves at the two sites, the difference was most
pronounced at FEX where fresh leaves had twice the biomass
of insects on them than did autumn leaves at that site.
Variance for biomass values was reduced when functional
feeding groups and individual taxa were considered.
Shredder biomass (including the shredder chironomid,Brillia
flavifrons) on fresh leaves was at its peak on Day 24 at
both sites (Fig. 6.7). Although this peak is obvious for
autumn leaves at FCD, shredder biomass was consistently high
from Day 24 onward at FEX (Fig. 6.7). A high proportion of
the shredders was attributable to B. flavifrons. Its growth
patterns on fresh versus autumn leaves has been previously
reported for the Ford River at a site between FEX and FCD
(Stout and Taft, 1985). When shredder biomass values (ex-
cluding B. flavifons) are adjusted for leaf biomass values,
they are the highest on Day 54 (figs 6.8 - 6.9). This is
particularly true for shredders on fresh leaves at both
sites (Fig. 6.8). Brillia flavifrons mean dry weight per
individual values increased from 0.0415 mg/individual at Day
24 to 0.1027 mg/individual at Day 91 on fresh leaves. On
autumn leaves, the average at Day 24 was 0.0344 mg/individual
and increased only to 0.0549 by Day 91 (Fig. 6.10). The
mean dry weight per individual values for fresh leaf data
were significantly higher than for autumn leaf data (t =
3.614, df= 39, p = 0.0004). (As few individuals were found
on Day 3 leaves, that collection date was excluded from
analysis.) Fresh leaves supported increasingly larger
individuals of this shredder than did autumn leaves.

The biomass of collector-gatherers was also higher on
fresh and autumn leaves at Day 24 (Fig. 6.11). One species,
Ephemerella invaria, is a member of this functional feeding
group. The dry weight per individual increased over time on

116
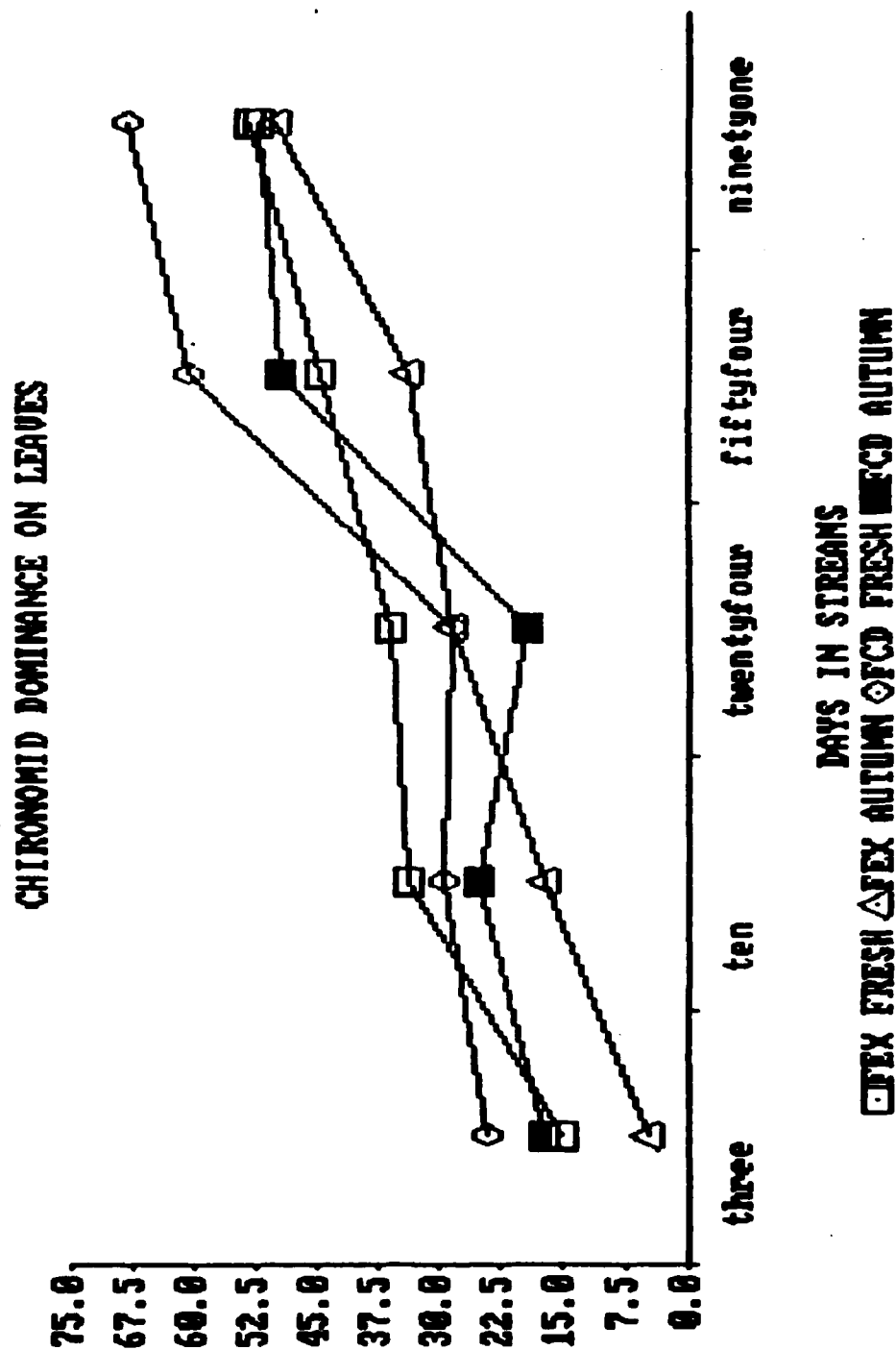
FIGURE 6.4 % DOMINANCE

Percent numerical dominance of Chironomidae (relative to all other individuals) on fresh and autumn leaves at FEX and FCD
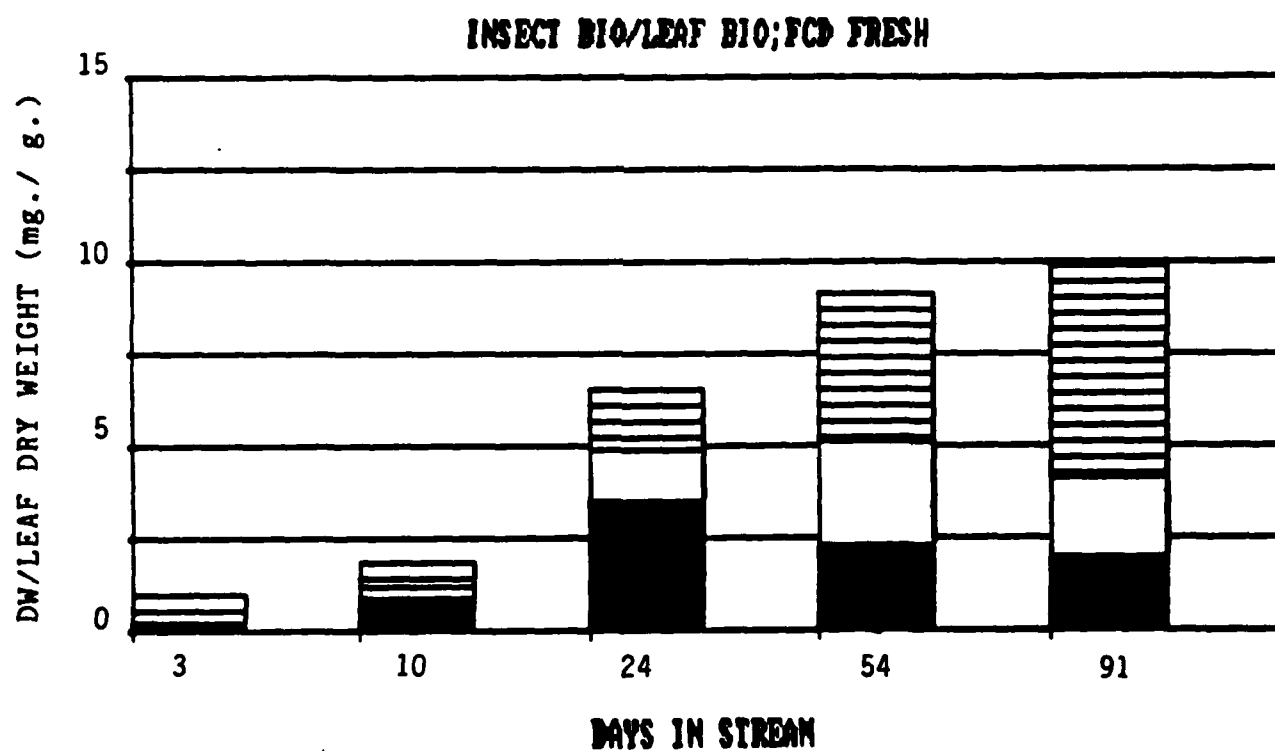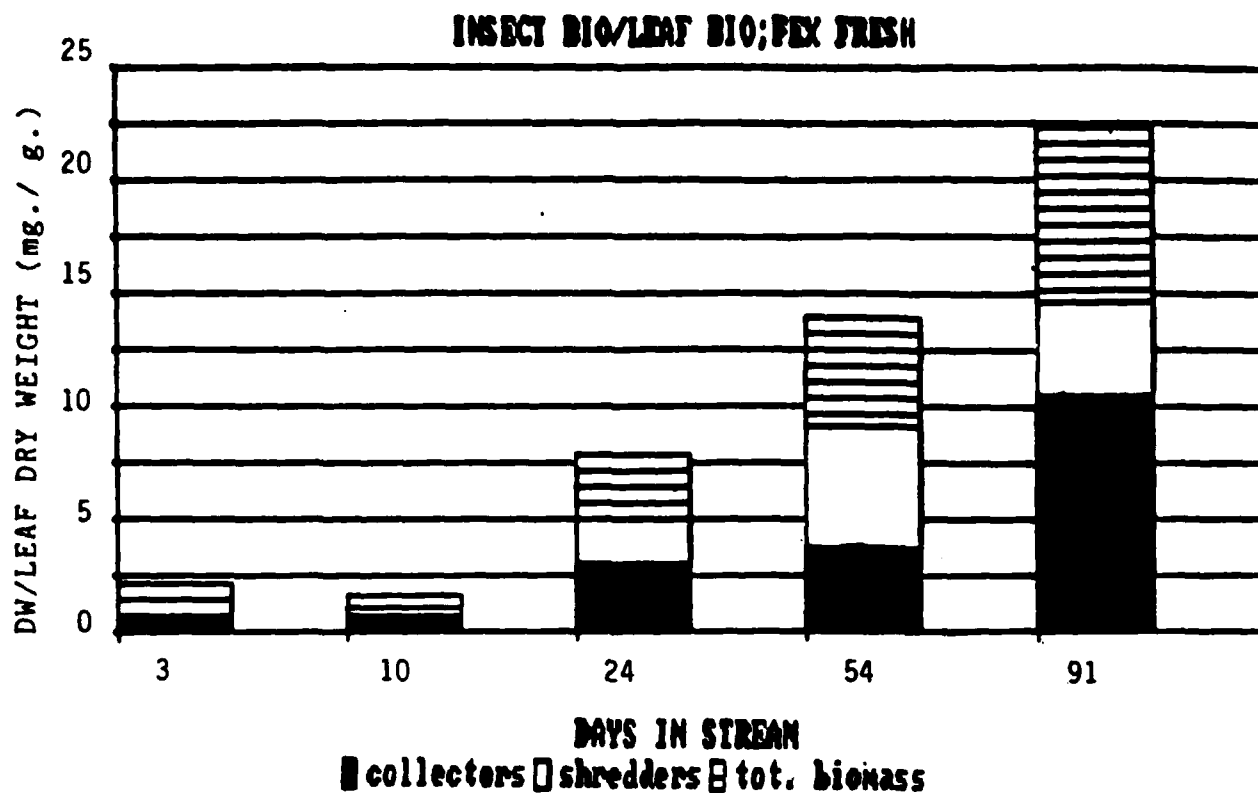
FIGURE 6.5

Total biomass of insects, with biomass of collectors and shredders
as subsets, on fresh leaves at FEX and FCD over time (September 19 to
December 27, 1984).
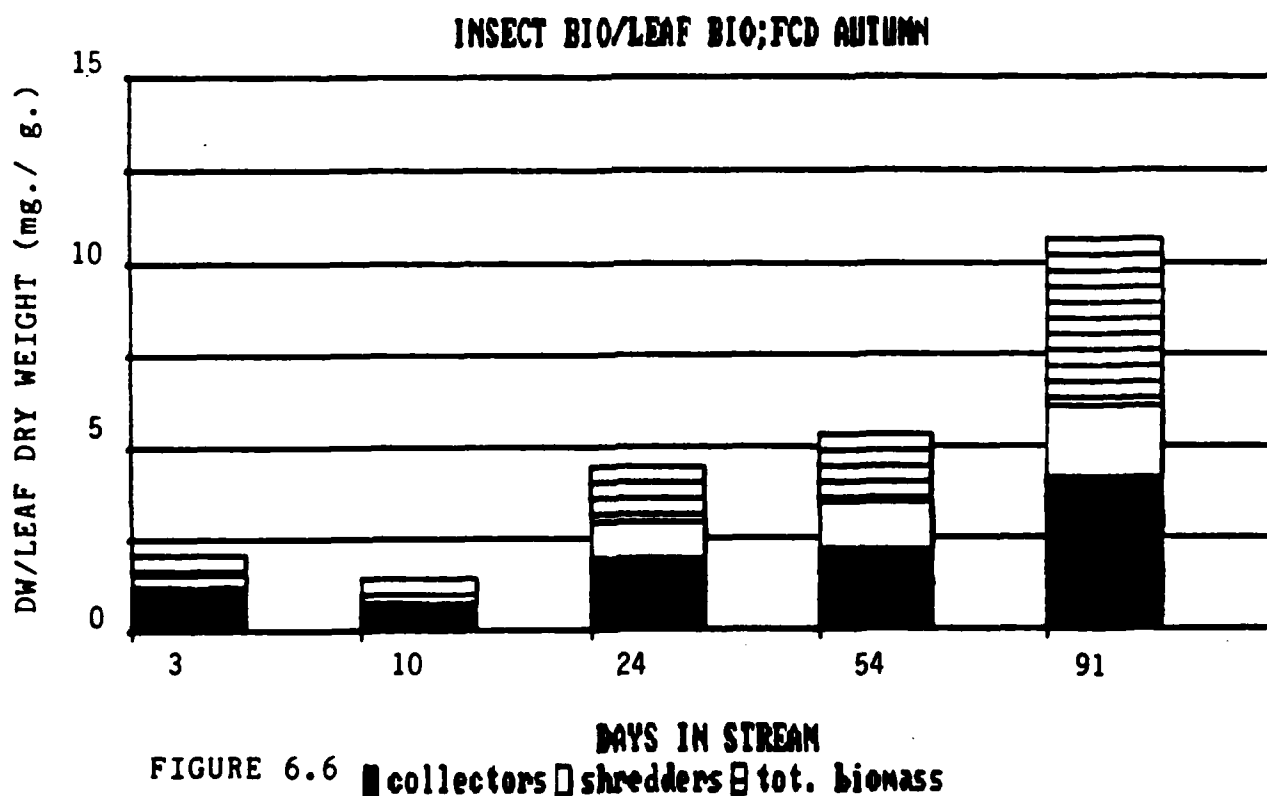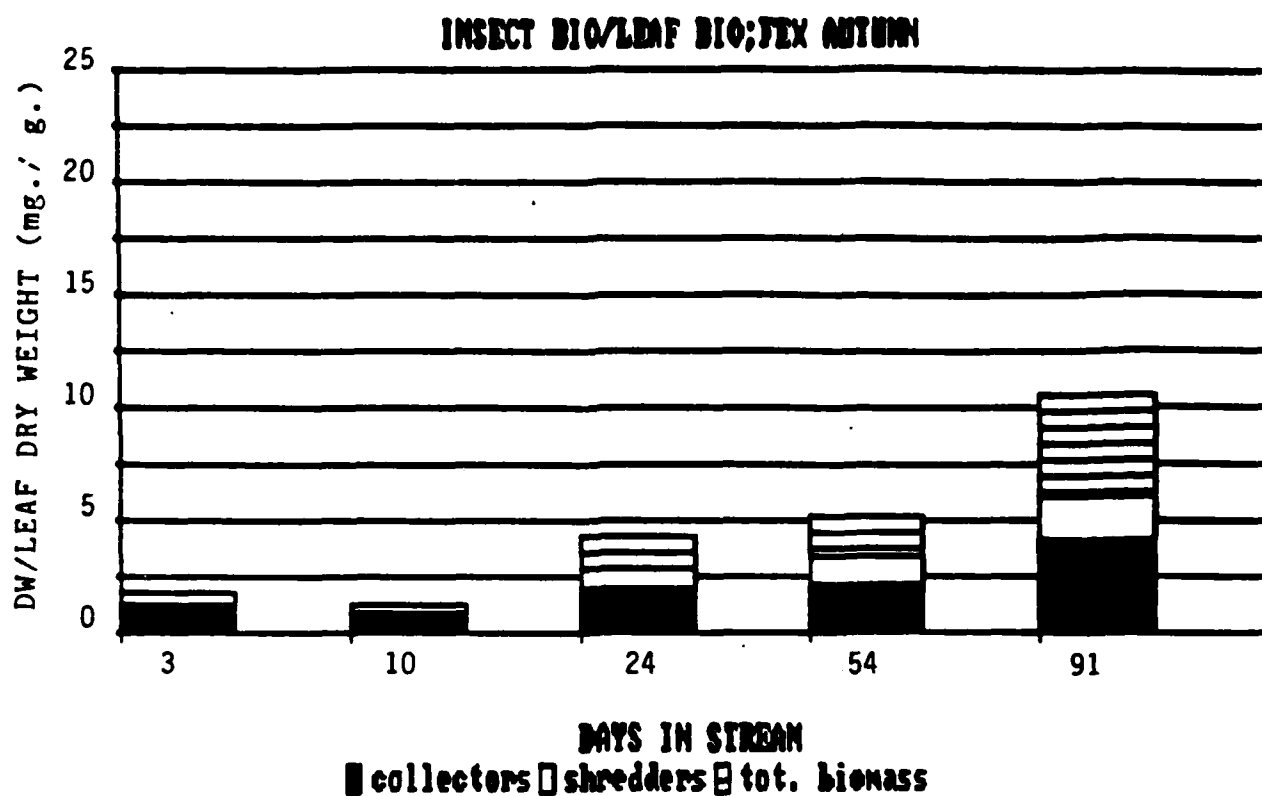
118

FIGURE 6.6

Total biomass of insects, with biomass of collectors and shredders
as subsets, on autumn leaves at FEX and FCD over time (September 19 -
December 27, 1984).
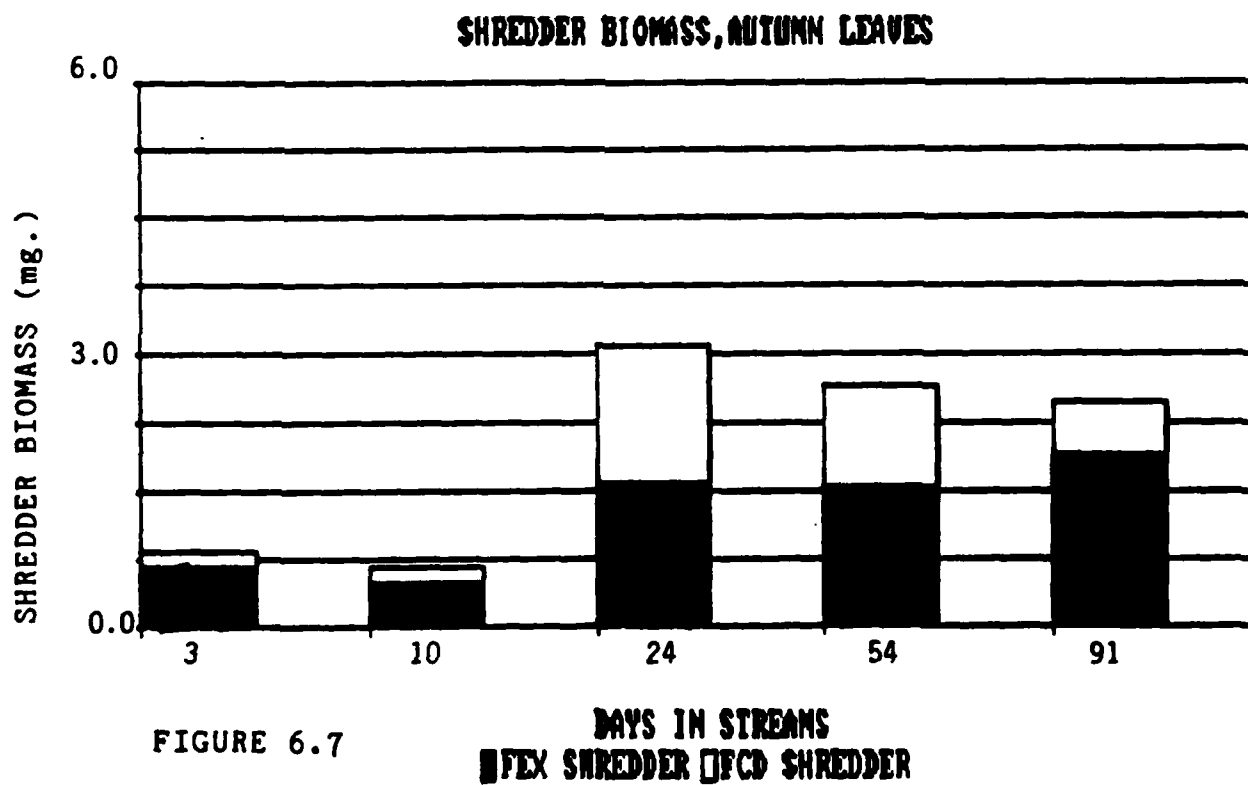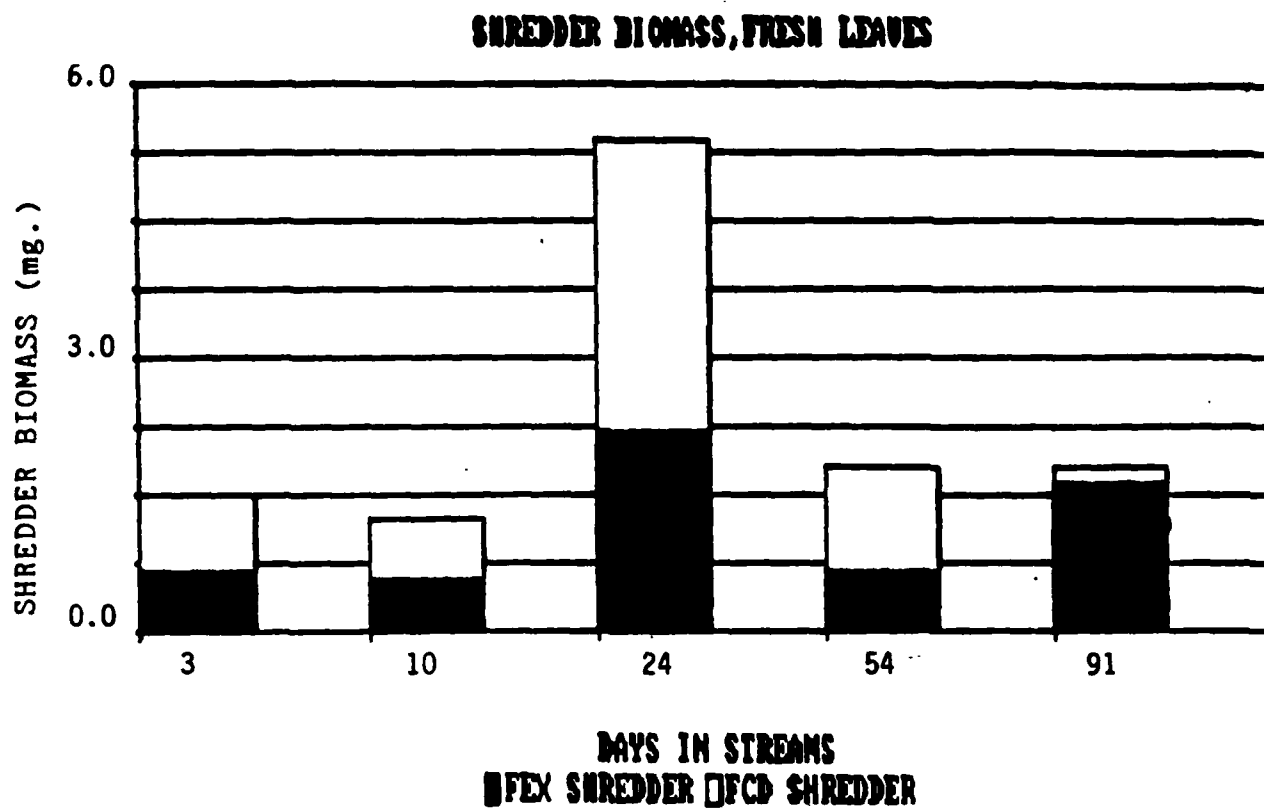
FIGURE 6.7

Shredder biomass of insects on fresh and autumn leaves at FEX and FCD over time (September 19 - December 27, 1984).
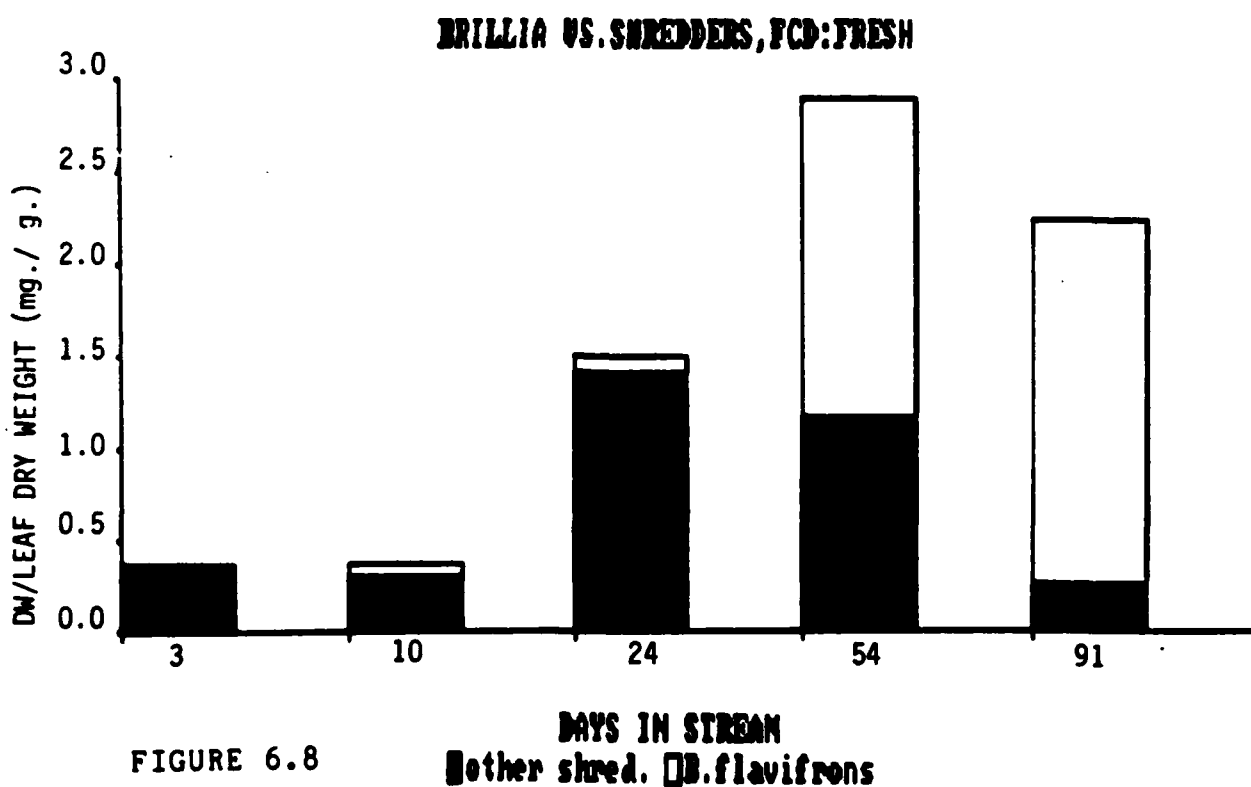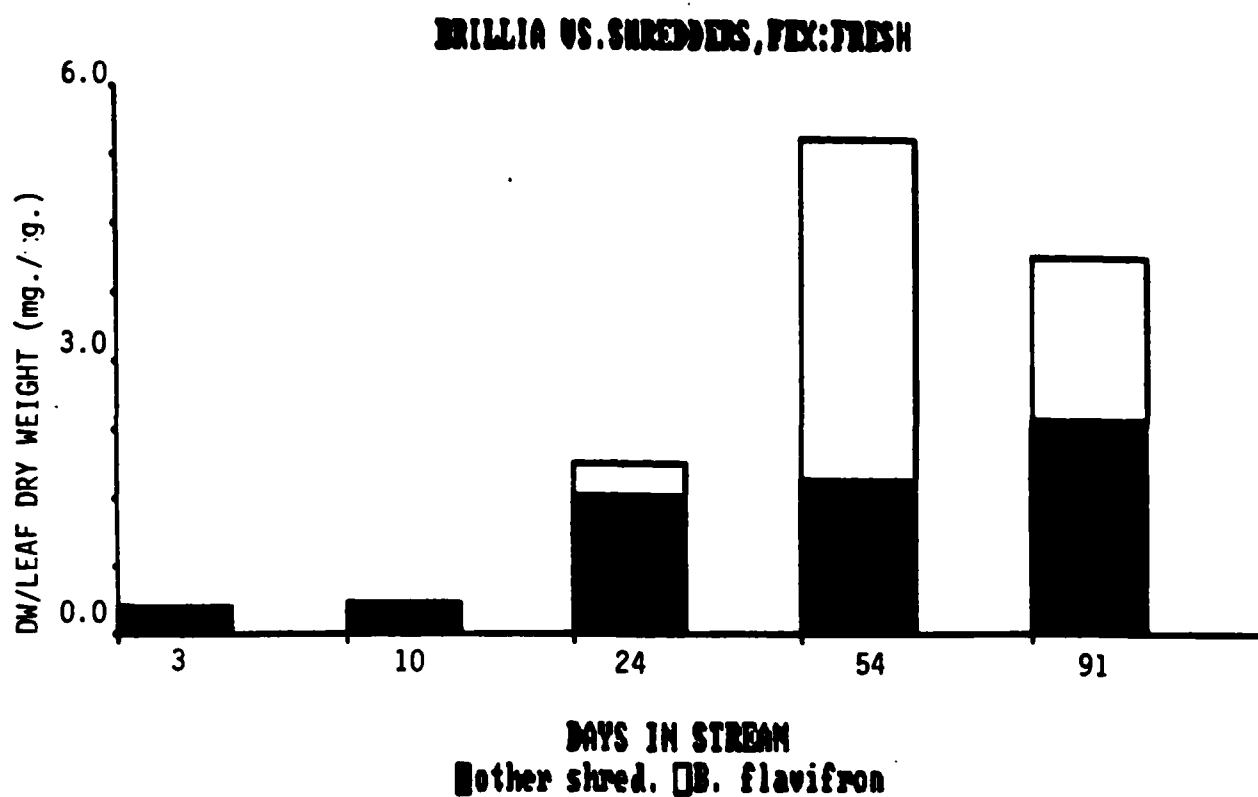
**FIGURE 6.8**

Biomass of B. flavifrons (white bars) versus all other shredders (black bars) on fresh leaves at FEX and FCD over time (September 19 - December 27, 1984)

BRILLIA VS. SHREDDERS FEX AUT

BRILLIA VS. SHREDDERS, FCD: AUT.
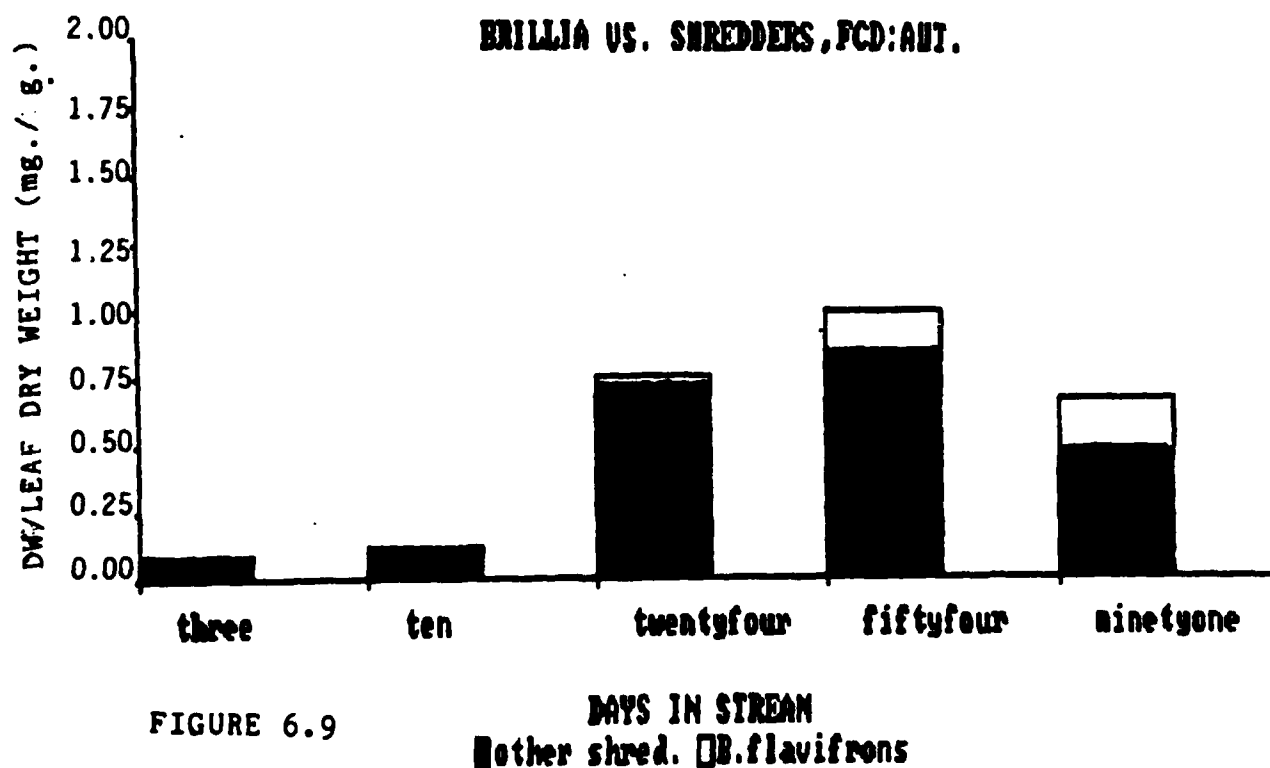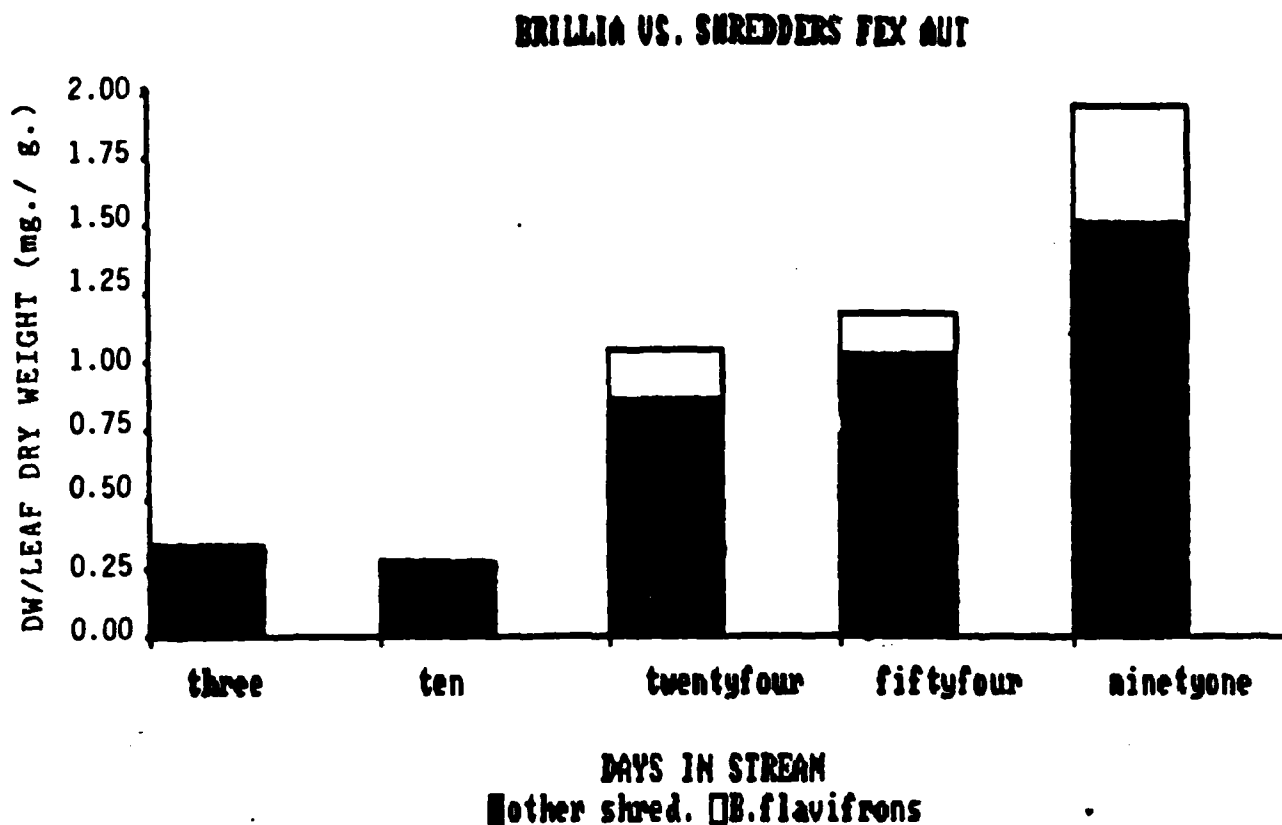
FIGURE 6.9

Biomass of B. flavifrons (white bars) versus all other shredders (black bars) on autumn leaves at FEX and FCD over time (September 19 - December 27, 1984)
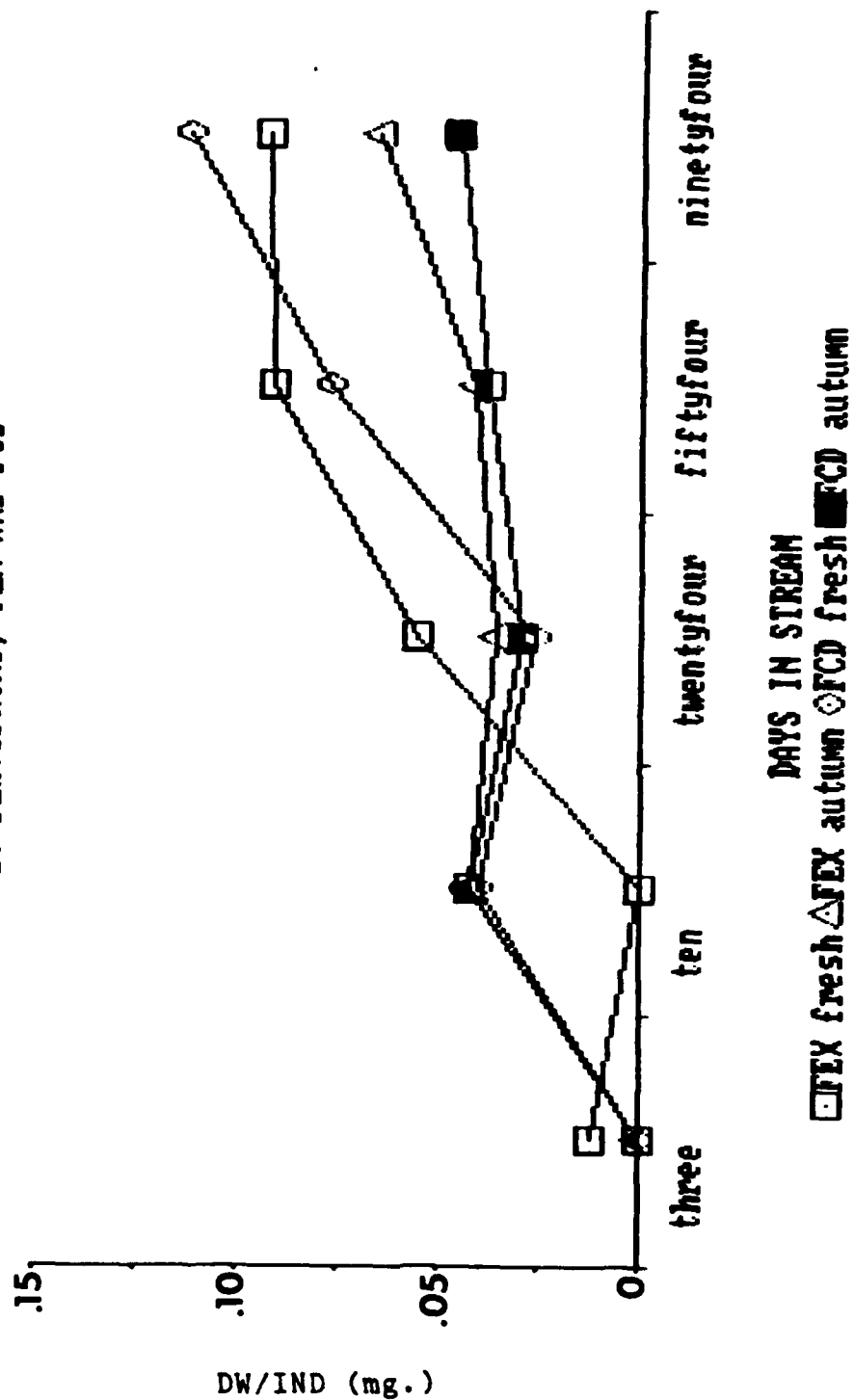
FIGURE 6.10 Growth rates of B. flavifrons on fresh summer and autumn senescent leaves at FEX and FCD, 1984

## COLLECTOR BIO., FRESH LEAVES

COLLECTOR BIOMASS (mg.)

15

10

5

0

3    10    24    54    91

DAYS IN STREAMS
■FEX COLLECT. □FCD COLLECT.

## COLLECTOR BIO., AUTUMN LEAVES

COLLECTOR BIOMASS (mg.)

15

10

5

0

3    10    24    54    91

DAYS IN STREAMS
■FEX COLLECT. □FCD COLLECT.
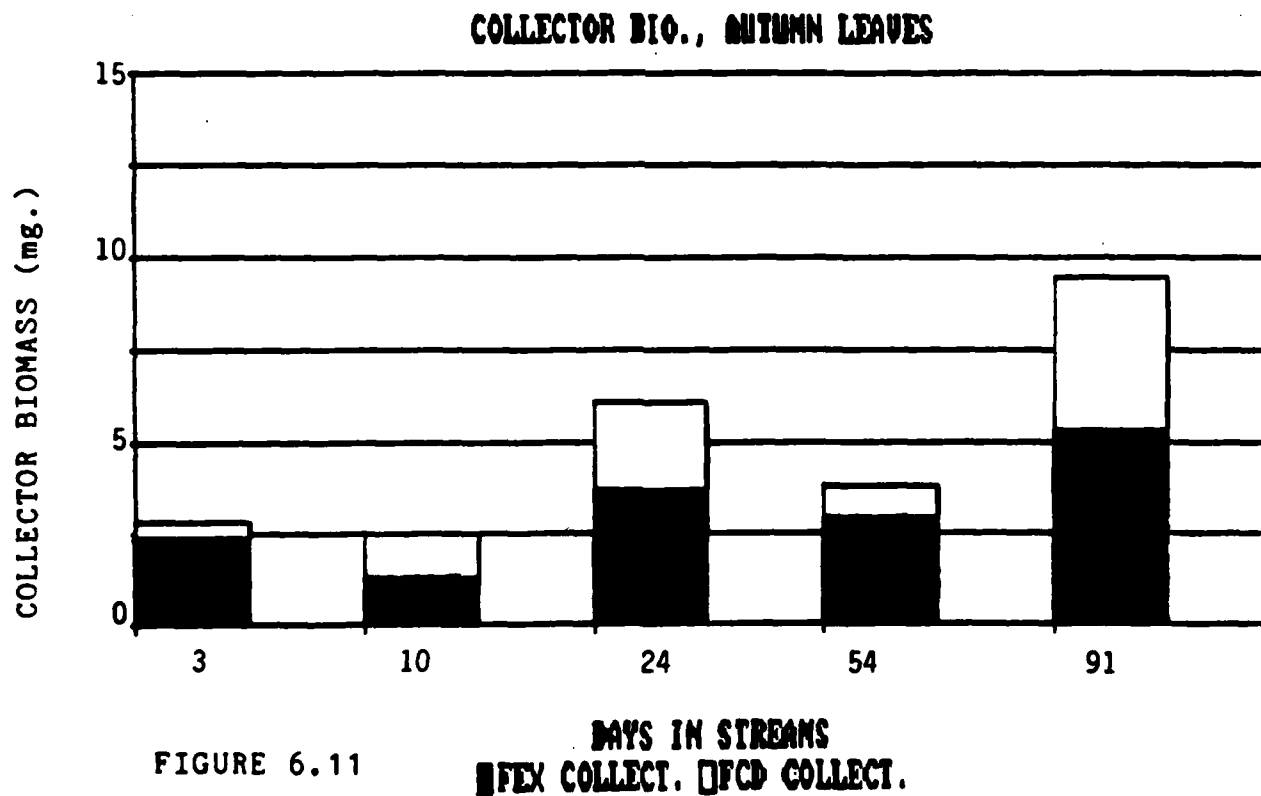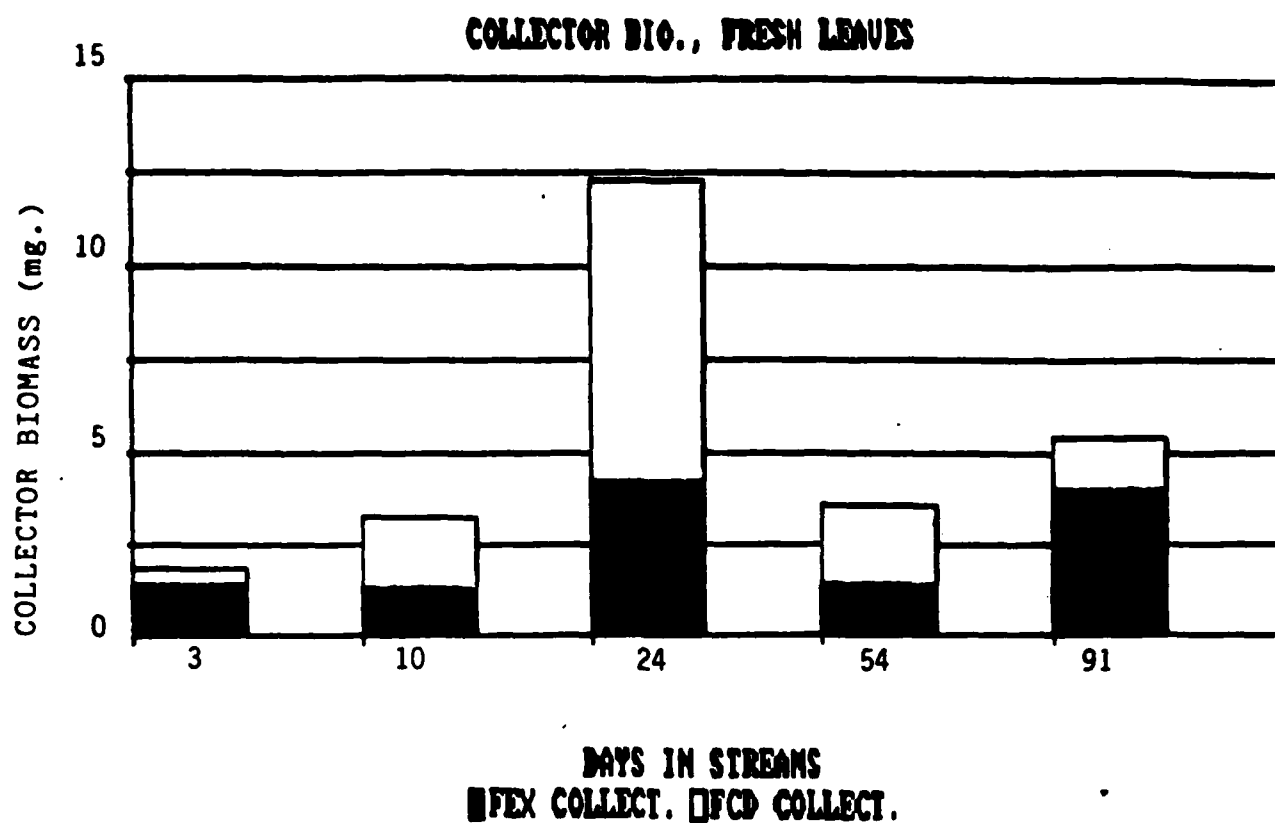
FIGURE 6.11

Collector-gatherer biomass on fresh and autumn leaves at FEX and FCD over time (September 19 - December 27, 1984).

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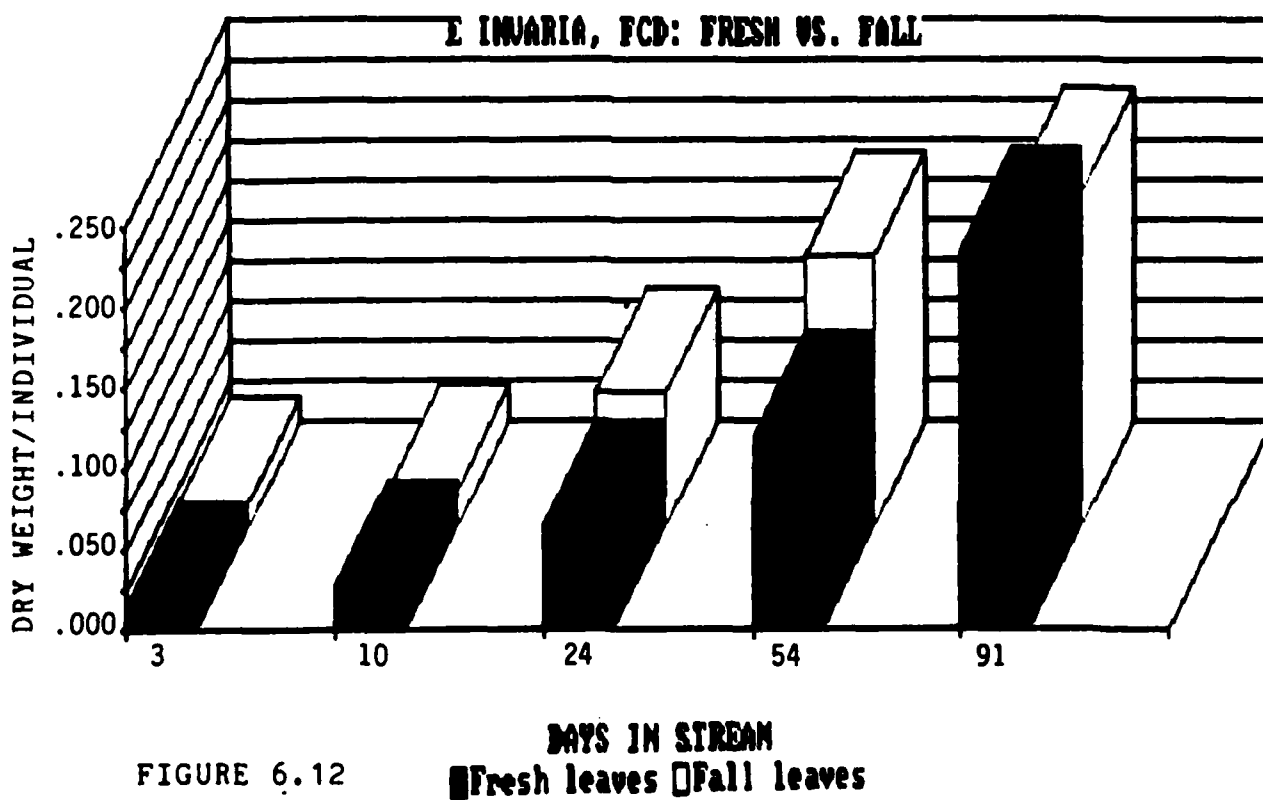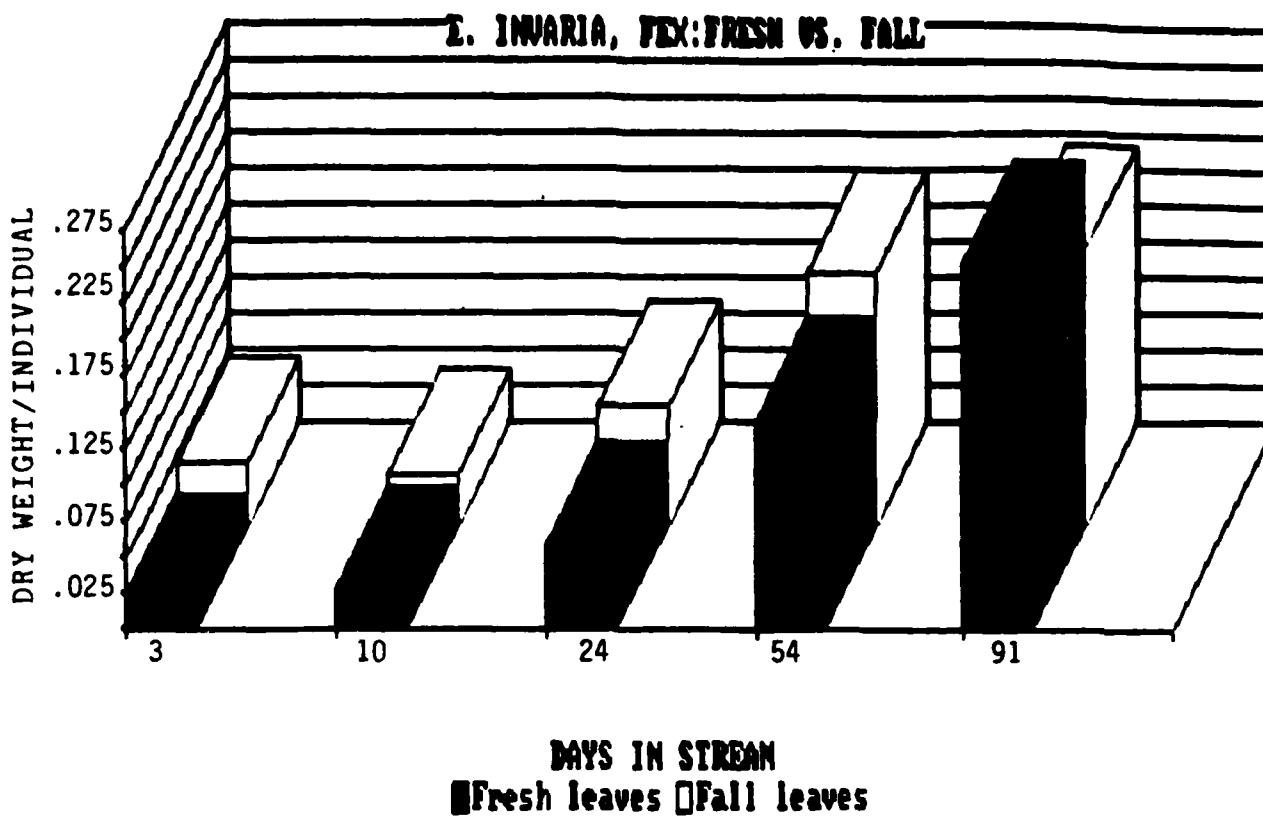
## FIGURE 6.12

Mean dry weight per individual of E. invaria on fresh and autumn leaves at FEX and FCD over time (September 19 - December 27, 1984).

fresh and autumn leaves at the two sites (Fig. 6.12). Neither leaf physiological state nor site had an affect on the mayfly's dry weight per individual values.


## Comparisons Among 1982, 1984 and 1985 data

Leaf Processing Rates.-- 1982-1983 data were from a site (FS1) on the Ford River, which is between FEX and FCD (see 1984 Annual Report and Stout et al. 1985). A two-tailed t-test for differences between slopes for a linear regression of fresh leaf dry weights at FS1 in 1982-1983 (days 3 through 111) and at FCD in 1984 (days 3 through 91) showed no significant difference (t = 1.778, d.f. = 45, p < 0.05). Autumn abscissed leaves also showed no significant difference in slopes (t = 1.000, d.f. = 45, p < 0.05). Although leaves for the last collection date in 1985 (Day 91) have not been collected at this writing, similar t-test were run for 1984 and 1985 data comparisons. Thus far, there is a significant difference between slopes for 1984 (-k = 0.0152) versus 1985 (-k = 0.0363) data for fresh leaves at FEX. There is, however, no significant difference for fresh leaves at the FCD site. (The processing coefficient in 1984 was -0.0150 and in 1985 it was -0.0147 at FCD; t = 0.281, D.F. = 49, p = 0.05.)

The high -k values for fresh leaves at FEX may have been caused by extensive flooding and concomitant scouring prior to Day 54 collections (see Fig. 1.3). If the data from collections on Day 91 at FEX show a similar pattern, the -k value for fresh leaves there in 1985 will significantly exceed all prior results. An extensive rainy period in the fall of 1985 may have affected results at FEX more than at FCD, owing to higher average velocities at FEX. No other explanation can be given at this time. Fresh leaves were treated in the same manner and placed in the two sites at similar times in 1984 (19 September) and 1985 (17 September). Autumn leaf comparisons between the two years were not made as the prior year's leaves were not available and fall leaves had not yet abscissed in 1985 when fresh leaves were put in the stream. That year, leaves were collected from trees and dried at 60oC for 48 hr before being put in the stream. Thus, those leaves will only be used as comparisons between fresh and dried leaves of the same age. In 1986, fresh leaves will be placed at FEX and FCD in mid-September and autumn leaves will be added as soon as abscission occurs. (This method was used in 1982-1983. Results were similar for those years and 1984 where the previous years' autumn leaves were used so that fresh and autumn leaves could be placed in the stream at the same time.) In 1985, a regression between initial fresh weight and dry weight of 200 fresh leaves had an r2 of 0.98. We

now can more accurately estimate initial dry weights of fresh leaves before putting them in the stream. (In prior years, we had used leaf area as the independent variable.)

Structural Community Parameters.-- Only the 1982-1983 seasons and the 1984 season data will be compared, as processing of insects on leaves for 1985 will not be completed until early in 1986.

The patterns for diversity (H') changes over time were similar between 1982 and 1984 after the initial conditioning phase (3 days). In both years, diversity continually declined over time. The same patterns existed for evenness (J') for both leaf treatments. Numbers of species (S) increased for the first month's incubation period in 1982 and 1984, but in 1982, there was a more pronounced decrease thereafter, as compared with 1984 (See 1984 Annual Report, Figure 6.3). As for 1982, the major increase in numbers of individuals was attributable to chironomids whose percent dominance over time significantly increased on both leaf treatments at the sites used in 1982 and 1984. This affected H' and J' more than S, indicating that the colonization patterns on leaves does not reach stability by the time leaves are over 50% processed (See discussions by Tramer, 1969).

Functional Community Parameters.-- As for 1982-1983 data, shredder biomass was significantly higher on fresh than on autumn leaves. Much of the shredder biomass was attributable to one chironomid species, B. flavifrons. This shredder increased over time in numbers and in mean dry weight per individual for fresh versus autumn leaves in 1982-1983 and in 1984. Another functional feeding group, collector-gatherers, was also selected for analysis. Its biomass was significantly higher on fresh versus autumn leaves in the Ford River in 1982-1983 and at FCD in 1984. There was no significant difference at FEX in 1984. One collector-gatherer species, Ephemerella invaria, was treated separately in 1984. It increased in numbers and in mean dry weight per individual over time on fresh and autumn leaves at both sites.

### Future Plans for this Element

Coefficient of Variation (C.V.) values for -k, H', J', S and biomass of selected species were low. Using a power test, five replicates per treatment were sufficient over most of the collection dates to state that 95% of the time the true mean was within ± 40% of the estimated mean at an alpha level of .05. Even so, seven replicates per treatment per collection date were taken in 1985 to increase the probability that CV values would be below 18% for the parameters throughout all collection periods.

In the future, fresh leaf dry weight estimates will be determined by taking fresh leaf weights and then finding their estimated dry weights using linear regression analysis of fresh versus dry weights of leaves.

All parameters previously used will continue to be followed at the FEX and FCD sites. Prior and future leaf processing rates will be treated in degree days. Changes in predator biomass along with selection of the most common predator species will also be included for prior and future data sets for this element.

## Summary

Leaf processing rates (-k) were not significantly different for 1982-1983 and 1984. H'and J' values were also similar. Numbers of species (S), however, remained higher over time in 1984 as compared with 1982-1983 data. Percent dominance of chironomids on leaves was similar for 1982 and 1984. One shredder, B. flavifrons, showed similar numerical and size-class patterns in 1982-1983 and 1984. A collector, E. invaria was added to the analysis in 1984. It had similar and consistent size classes for both fresh and autumn leaves at FEX and FCD. C.V. values were, for the most part, below 18%.

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# APPENDIX I

Copies of two papers published in 1985 as a result of work
for Element 6

# APPENDIX I

## Copies of two papers published in 1985 as a result of work for Element 6

### Growth Patterns of a Chironomid Shredder on Fresh and Senescent Tag Alder Leaves in Two Michigan Streams

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## ABSTRACT

A chironomid, Brillia flavifrons Johannsen (Orthocladinii) previously thought to specialize on decaying wood, consumed Tag Alder leaves (Alnus rugosa (Du Roy)) in two Michigan streams, Schwartz Creek and the Ford River. Schwartz Creek's substrate is primarily sand and the principle allochthonous inputs are White Cedar (Thuja occidentalis L.) needles and wood. The Ford River's substrate contains cobble and gravel. The primary inputs are deciduous leaves, with the majority being Tag Alder. Fresh Tag Alder leaves are commonly found in streams in the western Upper Peninsula, owing primarily to high beaver activity and secondarily to wind activity. Substantial green leaf inputs occur at a time when the previous year's leaves have been processed. In Schwartz Creek, B. flavifrons may be the primary shredder species, as the biomass of B. flavifrons exceeded the biomass of all other shredder insect species combined on fresh green Tag Alder leaf packs and autumn senescent Tag Alder leaf packs. This chironomid appears to prefer to feed on fresh leaves: Larval mean biomass and field growth rates were significantly higher on fresh than on autumn leaves. In the Ford River, B. flavifrons is not the primary shredder, as the biomass of other shredder species exceeded the biomass of B. flavifrons on both leaf types. In the Ford River, B. flavifrons appears to prefer to feed on fresh leaves more than autumn leaves: Larval mean sizes were significantly higher on fresh than on autumn leaves. We hypothesize that (1) fresh green leaves are chemically richer and have surfaces that are richer in microflora and microfauna to account for the increased growth rates and/or higher mean biomass values for B. flavifrons on fresh green leaves, and that 2) increased resource competition by other shredder species in the Ford River may account for the lower growth rates and/or lower mean biomass values of B. flavifrons observed on both leaf types in that river.

## INTRODUCTION

Chironomids can numerically dominate aquatic insect communities found on leaves in streams. Because chironomids are usually small, have a diversity of functional feeding groups (Merritt and Cummins 1984), and are difficult to identify, they are often treated as a family by researchers studying the roles aquatic insects play in leaf processing (Andersen et al. 1978, Cowan, et al. 1983, Egglishaw 1964).

During a previous study (Stout, et al. 1985) we found one large shredder chironomid, Brillia flavifrons, feeding on Tag Alder leaves. It was also a very common inhabitant on experimental leaf packs we placed in each of two streams in the Upper Peninsula of Michigan. The chironomid was not found in decaying wood. This species had previously been reported as being a wood feeder (Oliver and Roussel 1983), as well as possibly being a detritivore (cf. flavifrons, Coffman, et al. 1971). The species can be easily identified, and its life cycle is synchronous with fall leaf inputs. As our previous work indicated that fresh leaves appeared to be preferred over autumn leaves by the aquatic insect community, we asked whether B. flavifrons would have higher growth rates on fresh summer versus autumn senescent leaves. In this paper, we report changes in individual biomass values of B. flavifrons and other insect shredders inhabiting leaf packs of each leaf type in the two streams. We describe possible hypotheses to account for our results.

## SITE DESCRIPTIONS

The Ford River and Schwartz Creek are hardwater brook trout streams located in the western part (Dickinson Co.) of Michigan's Upper Peninsula (Fig. 1). Conductivity, alkalinity, dissolved oxygen, pH and hardness values were not significantly different between streams over the study period. Water temperatures were also not significantly different, and for one-half of the study, the rivers were ice-covered and waters remained near $4^{\circ}C$ (December through March). The Ford River (4th order at the study site) contains more cobble and granitic rock than does the sandy-bottom Schwartz Creek (3rd order at the study site). Tag Alder occurs along both streams and is the dominant species along the Ford River. White Cedar (Thuja occidentalis L.) is the dominant species along Schwartz Creek.
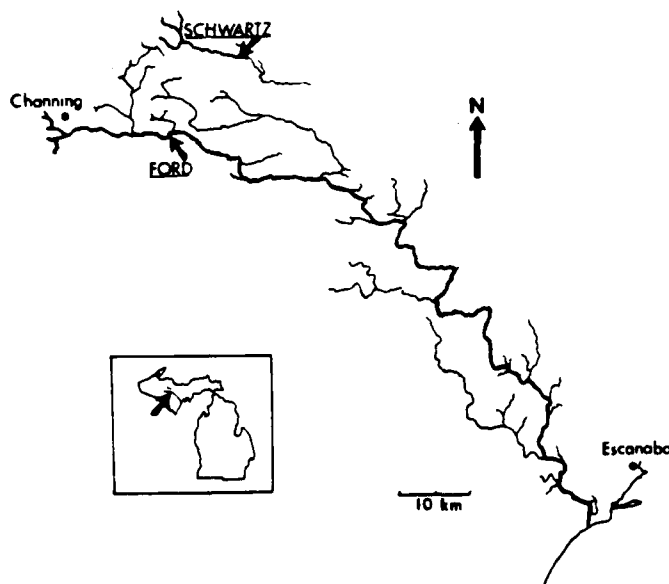


FIGURE 1:   Location of sampling stations for the Ford River and Schwartz Creek. Arrows indicate sampling stations.

## METHODS AND MATERIALS

### Brillia flavifrons

A. Identification.--The animals were keyed to genus, but positive species identification required associated larvae, pupae and adults. Animals were collected in February of 1983 from leaf packs placed in the rivers the previous September. After returning samples to Michigan State University, Brillia individuals were separated from other insects and then were returned to washed leaf material obtained from the original samples. Leaf materials and the larvae were incubated in $10^{\circ}C$ aerated water until pupation. Associated larval and pupal skins, along with the adults were sent to Leonard C. Ferrington at the University of Kansas for positive species identification. Voucher specimens are housed at the State Biological Survey at the University of Kansas.

B.    Feeding habits.—Gut contents from 10 individuals taken from February 1983 leaf packs were removed and analyzed under the light microscope. Fresh larval gut samples from other individuals were then excised and processed through standard ethanol series in preparation for scanning electron microscope studies (SEM). After critical-point drying, the samples were mounted on stubs and gold-coated for SEM microphotographs.

C.    Mean weight changes.—Individuals were counted and measured to the nearest mm. Biomass estimates were computed from individual lengths for each sample replicate, utilizing length-weight regression values from Smock (1980). Mean dry weight (mg.) per individual (MDW/IND) was calculated for each replicate sample. We make the assumption that changes in MDW/IND over time equal field growth rates even though emigration and immigration occurs on the leaf packs. After linear regression analysis for each treatment and site was performed, t-tests were used to test for larval field growth rate differences between fresh and autumn leaves within streams and between stream sites for each leaf treatment. In cases where t-tests showed no significant differences, ONE-WAY ANOVA tests were performed to test for mean differences in the MDW/IND values. Biomass estimates were also computed for other shredder insects (shredders after Merritt and Cummins 1984) in the samples. In cases where either B. flavifrons or other shredder species were absent from samples, those samples were excluded from the analysis.

## Leaf Treatments

A.    Autumn-abscissed leaves.—Litter traps for the daily collection of leaves were placed below Tag Alder shrubs in September 1982. Leaves were returned to the laboratory, oven-dried at 60°C for 48h, weighed into approximately 3g leaf packs (ten to fourteen leaves), wetted and then tied to bricks. Eighty bricks with attached leaves were placed in a riffle area in each stream on 22 September, 1982. Five individual bricks with attached leaf packs were collected after 3, 9 and 27 days, and then at monthly intervals from the Ford River until the end of March, 1983. Samples could not be retrieved from Schwartz Creek in February, 1983, owing to winter road conditions, and the last samples there were collected at the end of April, 1983. On collection days, the insects were rinsed from leaf packs into 60μm mesh sieves and then preserved in 70% ethanol. Leaves were dried at 60°C for 48h and re-weighed to determine loss rates over time.

B.    Fresh summer leaves.—Tag Alder leaves were picked from one grove on 27 August 1982. Leaves were picked at similar distances from branch tips to minimize differences in leaf age. Ten fresh leaves were then tied onto each brick, after measuring individual leaves for surface area, using a Licor Leaf Area Meter, Model 3100. Bricks were placed in each stream the same day as the leaves were picked. Incubation periods and processing of leaves and insects were as for autumn abscissed leaves, except that leaf areas were recorded pre- and post-immersion and dry weights determined post-immersion only. Initial dry weights of fresh leaf packs were approximately 3 g.

## RESULTS

The gut contents of B. flavifrons contained substantial amounts of leaf fragments, seen both at the light and SEM microscopic levels. Other chironomids were examined for leaf fragments, including Parametriocnemus Thienemann and Eukiefferiella Thienemann. None were found to contain leaf fragments.

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Brillia flavifrons field growth rates were significantly faster on fresh versus autumn leaf packs in Schwartz Creek (t = 2.67, d. f. = 52, p 0.01; Fig. 2). In the Ford River, there were no significant differences between fresh and autumn leaf packs (t = 0.25, d. f. = 52).

Figure 3 presents dry weights, adjusted to leaf dry weight losses over time, of B. flavifrons and other insect shredders on leaf packs. Fresh leaves from both streams contained a significantly higher biomass of all shredders (including B. flavifrons) than did autumn leaves in the two streams, after the initial 27 day colonization period (t = 5.31, d. f. = 86, p 0.001). For the same time period, the percent biomass of B. flavifrons, relative to the total biomass of all shredders on fresh leaves was significantly higher in Schwartz Creek than in the Ford River (t= 6.96, d. f. = 42, p 0.001).

Table 1 shows numerical and biomass data for B. flavifrons and other shredders over the entire study. Fresh leaves contained over two times the biomass of B. flavifrons compared with autumn leaves in Schwartz Creek; also the MDW/IND value was almost two times higher on fresh leaves. The total biomass of B. flavifrons on fresh leaves in the Ford River was 1.5 times higher than on autumn leaves, but the MDW/IND value was over two times higher on fresh versus dry leaves in the Ford River. In Schwartz Creek, the total number of individuals of other shredders was over three times higher on fresh than on autumn leaves; yet, the MDW/IND value was only one-tenth the value for autumn leaves. The discrepancy was owing to eight large limniphilids and tipulids found in two of the 36 samples. In the Ford River, the numbers were similar for fresh and autumn leaves.

## TABLE 1

Insect Shredders on Fresh and Autumn Leaves in Two Michigan Streams

| STREAM, TREATMENT | Brillia flavifrons | | | Other Shredders | | | |
| --- | --- | --- | --- | --- | --- | --- | --- |
| | Total Biomass (mg.) | Total No. | MDW/IND (mg.) | Total Biomass (mg.) | Total No. | MDW/IND (mg.) | No. Sam-ples |
| SCHWARTZ CREEK | | | | | | | |
| Fresh Leaves | 208.63 | 306 | 0.68 | 16.9 | 149 | 0.11 | 35 |
| Autumn Leaves | 92.04 | 240 | 0.38 | 49.8* | 43 | 1.16 | 36 |
| FORD RIVER | | | | | | | |
| Fresh Leaves | 34.79 | 146 | 0.24 | 111.02 | 498 | 0.22 | 36 |
| Autumn Leaves | 22.57 | 215 | 0.11 | 73.52 | 485 | 0.15 | 37 |

*Inflated value, owing to 5 large limniphilids and 3 large tipulids from two samples.

## DISCUSSION

Brillia flavifrons had significantly higher field growth rates on fresh than on autumn leaves in Schwartz Creek (Fig. 2). As B. flavifrons grew larger on fresh leaf packs in Schwartz Creek, and the leaf packs in that creek contained fewer numbers and lower biomass values for other shredder species, B. flavifrons may play the major role relative to other aquatic insect shredders in leaf litter processing in Schwartz Creek. In the Ford River, the biomass of other shredder species was higher than the biomass of B. flavifrons on both leaf treatments. In the Ford River other shredder species biomass values (but not numerical values) were higher on fresh than on autumn leaf packs.

The lower MDW/IND values for B. flavifrons on the Ford autumn leaves than on Schwartz autumn leaves may be related to competitive resource utilization by the other shredder species in the more diverse Ford River autumn leaf packs. Brillia flavifrons individuals inhabiting either fresh or autumn leaves were significantly larger in total length in Schwartz Creek than in the Ford River. We hypothesize that this shredder species experiences more resource competition on fresh and autumn leaf packs in the Ford River than in Schwartz Creek. Data supporting our hypothesis include: 1) processing rates of the leaves, 2) total insect biomass, and 3) total biomass of B. flavifrons compared to other shredder species. However, we do not rule out the possibility that characteristics of the two streams (substrate type, allochthonous inputs, etc.) contributed substantially to the between stream differences.

Previous work (Stout, et al. 1985) showed that fresh leaves were processed faster in the Ford River ($-k$ = 0.0171) than in Schwartz Creek ($-k$ = 0.0126), and that autumn leaves were processed faster in the Ford River ($-k$ = 0.0086) than in Schwartz Creek ($-k$ = 0.0058). Higher processing coefficients ($-k$) for fresh leaves in the Ford and Schwartz Creek were correlated with higher species diversity (H'), higher species richness (J') and higher total insect numbers on fresh than on autumn leaves. In the present study, numbers and total biomass of B. flavifrons were lower on both fresh and autumn leaves in the Ford than on fresh and autumn leaves in Schwartz Creek. Numbers and total biomass of other shredder species were higher on fresh leaves in the Ford River than on fresh leaves in Schwartz Creek.

It is possible that fresh leaves serve as more "nutritious" substrates for insect shredder species. Fresh leaves were more slimy to the touch for the first two months of the study. SEM studies are currently underway to ascertain the composition of the epiphyllic layers.

Aquatic insect shredders gain more in growth and maintenance on certain species of autumnal leaves than on others (Andersen and Cummins 1979, Andersen and Sedell 1979, Iverson 1974, Kaushik and Hynes 1971, Otto 1974, 1075, Petersen and Cummins 1974). Autumn senescent leaves may provide resources distinctive from fresh green leaves for the same species of leaf; e.g., Otto (1974) found that the caddisfly larva, Potamophylax cingulatus L. preferred green to withered alder leaves (L. glutinosa L.). Fresh green and autumn senescent leaves from a single species of plant may contain nutritional resources more distinctive from one another than nutritional resources represented among leaves of various plant species for either fresh green or autumn senescent leaves. Fresh green leaves are commonly found in the summer and early fall in northeastern streams of the United States where beaver activity is high (Naiman, et al. 1984; pers. obs.). Fresh green leaves enter after the previous year's autumn leaves have been mostly processed and also enter

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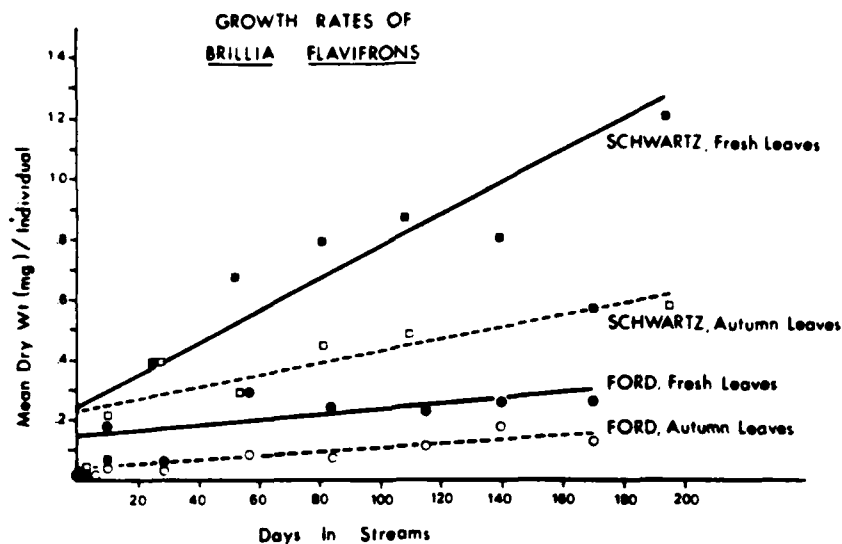
FIGURE 2: Field growth rates of B. flavifrons inhabiting leaf packs in Schwartz
Creek and the Ford River. Closed squares and solid connecting lines:
animals on fresh leaves in Schwartz Creek. Open squares and dashed
connecting lines: animals on autumn leaves in Schwartz Creek. Closed
circles and solid connecting lines: animals on fresh leaves in the Ford
River. Open circles and dashed connecting lines: animals on autumn
leaves in the Ford River.
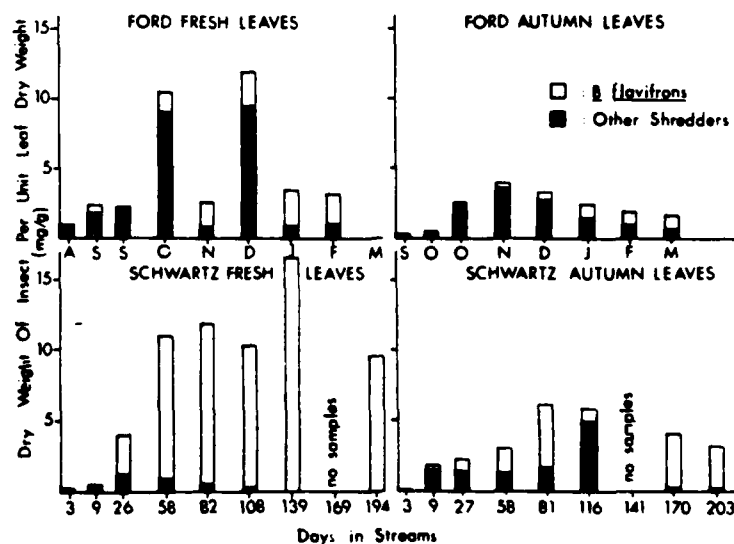


FIGURE 3: Comparison of B. flavifrons mean biomass values to other insect
shredder mean biomass values. (Values adjusted for reduced leaf
biomass over time. Samples without B. flavifrons or other insect
shredders were excluded from the analysis.)

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prior to major abscission for the present year. Not only may green leaves serve as more nutritious substrates, but for a time, they will be more commonly encountered than autumn leaves by the aquatic insect community.

## ACKNOWLEDGEMENTS

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# Patterns of macroinvertebrate colonization on fresh and senescent alder leaves in two Michigan streams

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SUMMARY. 1. Communities of invertebrates colonizing senescent autumn and fresh summer alder leaves (*Alnus rugosa*) were compared. Leaf packs for each treatment were placed in two hardwater streams in the Upper Peninsula of Michigan in late summer and early autumn. One stream has a cobble-bottom and the other a sand-bottom and both receive fresh leaf inputs by beaver fellings.

2. Fresh leaf packs remained intact after 26 days immersion, but thereafter were processed faster than were the autumn leaf packs in both streams.

3. In the cobble-bottom stream taxon richness (*S*), numbers of individuals and biomass were higher on fresh than on autumn leaves.

4. Fresh leaves in the sand-bottom stream supported a more diverse (*H'*), richer (*S*) and more equitably distributed (*J'*) insect fauna than did the autumn leaves.

5. We discuss the simultaneous lack of fresh leaf loss and the presence of more complex insect communities on those leaves during the first 26 days of the study. Invertebrates in both mid-latitude heterotrophic streams and in tropical lowland wet forest streams may rely on fresh leaf inputs, which have received little attention.

Key words. Aquatic insects, Michigan streams, leaf processing, summer fresh leaves, autumn senesced leaves.

## Introduction

Leaves in tropical lowland wet forests fall rather asynchronously throughout the year, and most leaf litter input to streams consist of undried green leaves (Stout, 1980, 1981). This contrasts with many deciduous forest streams in mid-latitudes where most leaf input occurs in the autumn (Gosz, Likens & Bormann,

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1972; Webster, 1983). Research on organic matter processing in streams has occurred primarily in mid-latitude regions and has been focused on the fate of autumnal abscissed leaves (Minshall, 1967; Kaushik & Hynes, 1968; Cummins *et al.*, 1973; Petersen & Cummins, 1974; Anderson & Sedell, 1979).

However, substantial quantities of fresh green summer leaves do fall into deciduous forest mid-latitude streams (Merritt & Lawson, 1979; Mahan, 1980). This is particularly true for streams that support high beaver (*Castor*

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*canadensis* Kuhl) populations (Naiman, McDowell & Farr, 1984). Streams in the Upper Peninsula of Michigan can receive substantial amounts of fresh leaves when beaver fell riparian vegetation. Beaver activity was extensive along the two stream courses where we studied the effects of summer and autumn abscissed leaves on aquatic macroinvertebrate communities.

Our objectives were: (1) to determine processing rates and insect colonization patterns of fresh and senescent alder leaves in two Michigan streams. and (2) to present experimental results supporting the hypotheses that fresh leaves provide a food resource for aquatic insects prior to autumnal leaf fall.

## Materials and Methods

### Field sites

The Ford River and Schwartz Creek (Dickinson County) are hardwater brook trout (*Salvelinus fontinalis* (Mitchill)) streams. The Ford River (fourth order at the study site; Strahler, 1957) is a cobble-bottom stream. Speckled Tag Alder (*Alnus rugosa* (DuRoy) Spreng), Balm of Gilead (*Populus gileadensis* Rouleau) and Red-Osier Dogwood (*Cornus stolonifera* Michx.) are the dominant species in the riparian vegetation. Schwartz Creek (third order) is a sand-bottom stream (the substrate of riffles was 80% and 25% sand in Schwartz Creek and Ford River, respectively) that flows through a cedar swamp dominated by northern white cedar (*Thuja occidentalis* L.) along with patches of *A. rugosa*.

### Autumn, abscissed leaves

Litter traps for the daily collection of leaves were placed below tag alder shrubs in September 1982. Leaves were returned to the laboratory, oven-dried at 60°C for 48 h, weighed into approximately 3 g leaf packs (ten to fourteen leaves) wetted and then tied to bricks. Eighty leaf packs were placed in a riffle area in each stream on 22 September 1982. Five replicates from each site were collected after 3, 9 and 27 days, and then at monthly intervals until the end of June 1983. On collection days, the macroinvertebrates were rinsed from leaf packs into 60 μm mesh sieves and preserved in

70% alcohol. Washed leaves were oven-dried to 60°C for 48 h and reweighed. Log$_e$ values of percentage dry weight of the leaf packs remaining between Day 3 and Day 115 (116 for Schwartz Creek) were used to calculate exponential processing coefficients (−k) (Petersen & Cummins, 1974).

Insects were initially identified to family and later to species for the October and January samples. Since most families were represented by a single species, community patterns were similar for both levels of identification. Diversity (Shannon-Weiner), richness and evenness indices were calculated. Biomass was estimated for each sample utilizing length-weight regression values (Smock, 1980). One-way ANOVA tests for differences over time were calculated for each variable.

### Fresh summer leaves

Tag alder leaves were picked from one grove on 27 August 1982. Possible effects owing to differences in leaf age were minimized by picking leaves similar distances from branch tips. Since we wanted to simulate natural fresh leaf inputs. we did not dry and weigh these leaves; rather, we kept them fresh by determining leaf areas for each leaf on a Licor Model LI-3000 leaf area meter. A linear regression of leaf area against dry weight for 100 leaves was computed to obtain estimates of initial dry weight for the summer leaves ($r^2$=0.89). As the coefficient of determination was below the level of desired accuracy for computation of −k values. percentage leaf area remaining was used. For the summer leaves, log$_e$ values of percentage leaf area remaining between day 9 and 111 (116 for Schwartz Creek) were used for computing −k values as leaves did not begin to lose area until Day 26. Ten fresh leaves per leaf pack were then tied onto bricks and placed in each stream the same day as picked. Collection, processing and analyses were as for autumn-dried leaves. except that in addition to weighing dried leaf packs, individual leaf areas were also measured for comparison with initial leaf area measurement. Leaf dry weights were used for computing insect biomass per unit leaf biomass values.

Fresh leaves were placed in the streams 1 month (27 August) prior to autumn abscission.

At that time mean water temperatures were: Ford, 11.5°C (SE 2.8); Schwartz, 11.9°C (SE 1.7). During the first month that autumn leaves were in the streams, the mean temperatures were 8.7°C (SE 2.8) for the Ford and 9.1°C (SE 2.8) for Schwartz Creek. Despite the higher temperatures, fresh leaves showed no leaf area losses during the first 26 days of immersion. This probably occurred because the cuticle on fresh leaves remained intact. Autumn leaves showed leaching losses during the first 3 days in the stream.

## Results

### Leaf processing

After 9 days, fresh leaves were processed significantly faster than autumn leaves in the Ford River ($t=2.58$, d.f.$=47$, $P<0.005$) and in Schwartz Creek ($t=2.72$, d.f.$=45$, $P<0.005$) (Fig. 1). The processing coefficients for autumn leaves in both streams were similar to values reported by Petersen & Cummins (1974) for a related species of alder (*Alnus glutinosa* (L.) Gaerth). Autumn leaves were processed significantly slower in Schwartz Creek than in the Ford River ($t=2.154$, d.f.$=53$, $P<0.025$); however, summer leaves were not processed significantly slower in Schwartz Creek ($t=0.938$, d.f.$=39$). The high value for autumn leaves in Schwartz on Day 26 was attributable to the leaves becoming partially buried in sand during a prior spate.

### Comparisons between insects inhabiting autumn and summer leaves in each stream

A list of taxa colonizing the leaf packs is given in Appendix 1. The diversity of insects inhabiting fresh leaves was higher than for autumn leaves during the first 26 days in both streams (Fig. 2). Although Ford leaf packs supported a more diverse insect community than did the Schwartz leaf packs (Fig. 2), the reduction in diversity over time for leaf packs in both streams was similar, and was highest during the first 2-month incubation period as compared with later incubation periods (Scheffé's Interval Test, $P<0.01$).

Family richness ($S$) values were significantly higher for insects inhabiting fresh versus autumn leaves in both streams over an 85 day
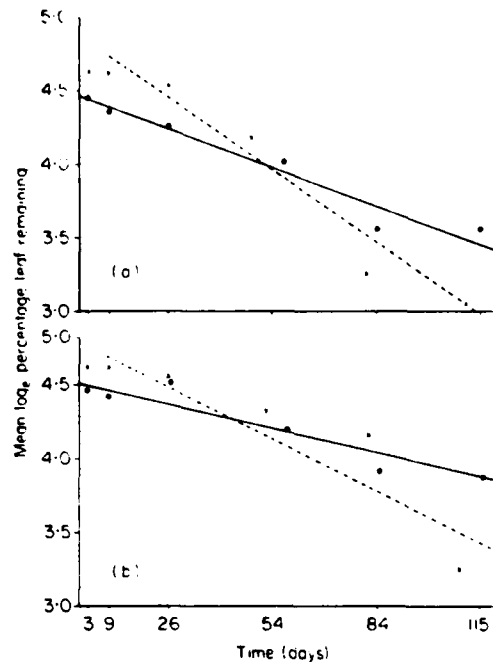


FIG. 1. Mean log$_e$ of percentage leaves remaining for autumn abscissed (●) and summer fresh leaves (×) in (a) Ford River and (b) Schwartz Creek. Solid lines = linear regression lines for autumn leaves; dashed lines = summer leaves. Linear regression values: Ford autumn leaves; $r^2=0.670$, $-k=0.0086$. Ford summer leaves; $r^2=0.532$, $-k=0.0171$. Schwartz autumn leaves; $r^2=0.790$, $-k=0.0058$. Schwartz summer leaves; $r^2=0.485$. $-k=0.0126$.

period (Table 1, Fig. 3) and Ford values were higher than Schwartz values. Taxon diversity ($H'$) and evenness or equitability values ($J'$) were similar for insects inhabiting both leaf treatments in the Ford River, but were significantly higher for fresh than for autumn leaves in Schwartz Creek (Table 1, Fig. 3). Although the numbers of rare families were similar for both streams, the numbers of individuals in the most abundant family, Chironomidae, were much higher in Schwartz Creek (a stream with substantial wood and white cedar needle inputs) than in the Ford leaf pack community. Thus, individuals were less equitably distributed among families in the sand-bottom creek than in the cobble-bottom creek. Additional ANOVA tests showed no significant differences for the indices after 85 days.

Total insect biomass per unit leaf biomass was significantly higher on fresh than on

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TABLE 1 One-way ANOVA tests for differences between autumn abscissed and fresh leaves remaining 81-85 days in the Ford River and in Schwartz Creek

| Site | Variable | Source | d.f. | MSS | F-ratio | F.prob. |
|---|---|---|---|---|---|---|
| Ford | Percentage leaf remaining | Day | 4 | 5259.14 | 36.20 | $P<0.001$ |
| | | Fresh v. Dry | 1 | 2764.70 | 19.03 | $P<0.001$ |
| | | Interaction | 4 | 198.12 | 1.36 | $P>0.20$ N.S |
| | | Error | 36 | 145.29 | | |
| | Diversity (H') | Day | 4 | 0.34 | 36.46 | $P<0.001$ |
| | | Fresh v. Dry | 1 | 0.00 | 0.04 | $P<0.05$ |
| | | Interaction | 4 | 0.01 | 0.70 | $P>0.20$ N.S |
| | | Error | 35 | 0.01 | | |
| | Richness (S) | Day | 4 | 5.12 | 45.53 | $P<0.001$ |
| | | Fresh v. Dry | 1 | 0.65 | 5.74 | $P<0.001$ |
| | | Interaction | 4 | 0.15 | 1.31 | $P<0.01$ |
| | | Error | 35 | 0.11 | | |
| | Evenness (J') | Day | 4 | 0.34 | 36.46 | $P<0.001$ |
| | | Fresh v. Dry | 1 | 0.00 | 0.04 | $P>0.20$ N.S |
| | | Interaction | 4 | 0.01 | 0.71 | $P>0.20$ N.S |
| | | Error | 35 | 0.01 | | |
| Schwartz | Percentage leaf remaining | Day | 4 | 2738.35 | 37.24 | $P<0.01$ |
| | | Fresh v. Dry | 1 | 1346.14 | 18.31 | $P<0.01$ |
| | | Interaction | 4 | 77.53 | 1.05 | $P>0.20$ N.S. |
| | | Error | 35 | 73.53 | | |
| | Diversity (H') | Day | 4 | 3.12 | 44.37 | $P<0.01$ |
| | | Fresh v. Dry | 1 | 10.42 | 148.40 | $P<0.01$ |
| | | Interaction | 4 | 1.14 | 16.19 | $P<0.01$ |
| | | Error | 35 | 0.07 | | |
| | Richness (S) | Day | 4 | 54.96 | 11.36 | $P<0.001$ |
| | | Fresh v. Dry | 1 | 210.80 | 43.59 | $P<0.001$ |
| | | Interaction | 4 | 13.72 | 2.84 | $P<0.05$ |
| | | Error | 35 | 4.84 | | |
| | Evenness (J') | Day | 4 | 0.28 | 15.75 | $P<0.01$ |
| | | Fresh v. Dry | 1 | 0.47 | 26.55 | $P<0.01$ |
| | | Interaction | 4 | 0.12 | 6.67 | $P<0.01$ |
| | | Error | 35 | 0.02 | | |
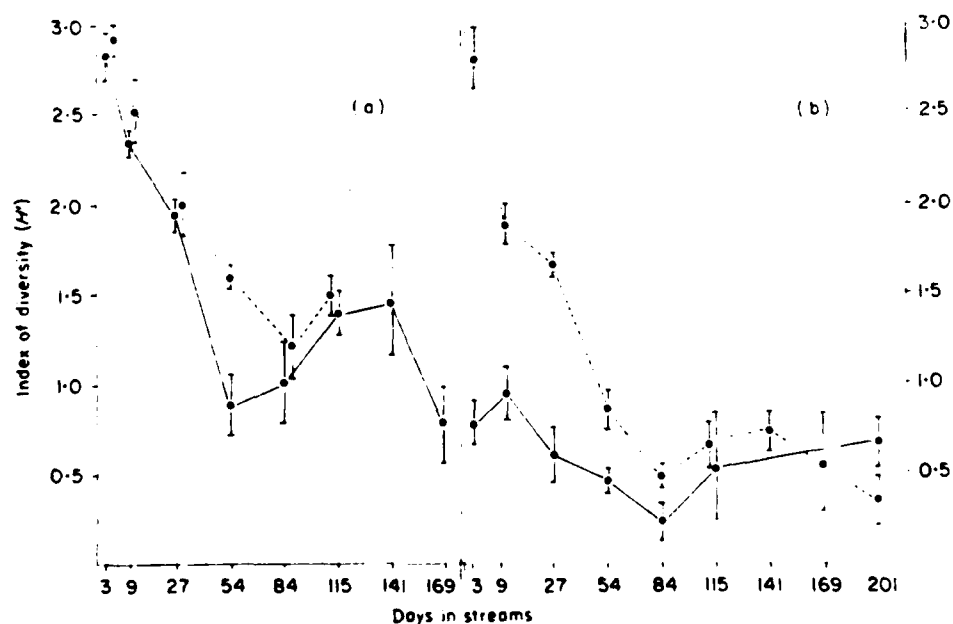


FIG. 2. Diversity (H') values for insects inhabiting autumn abscissed (—) and summer fresh leaves (---) in (a) Ford River and (b) Schwartz Creek. Bars represent standard errors.
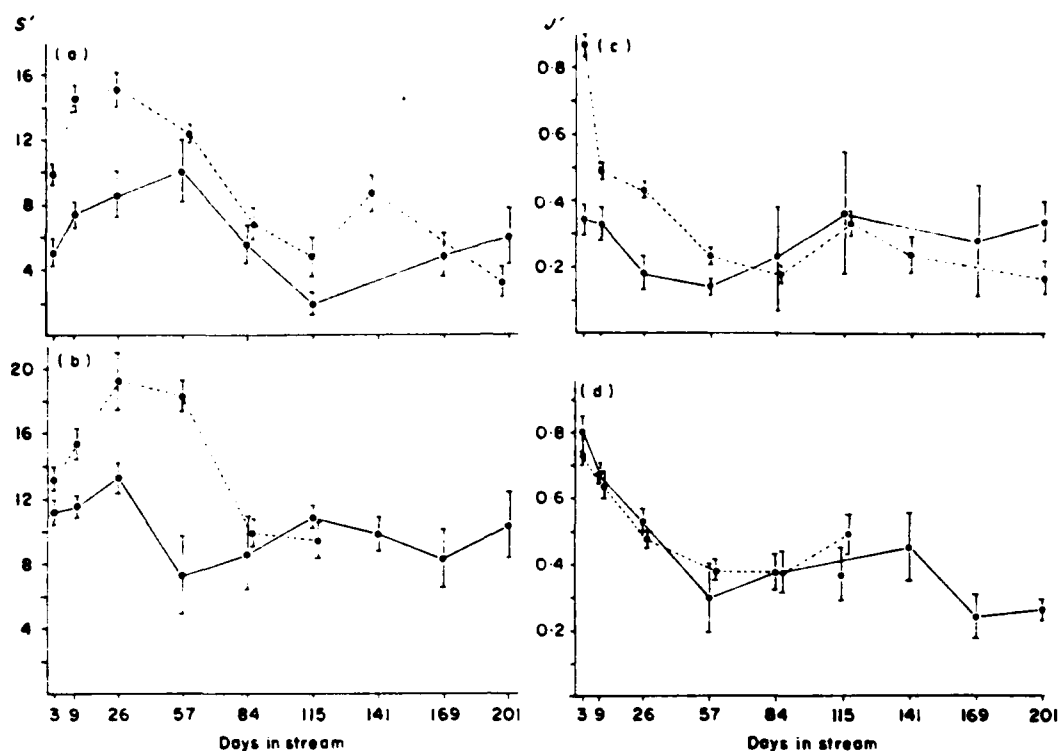
FIG. 3. Community values for insects colonizing autumn abscissed (—) and summer fresh (---) leaves: (a) and (b). family richness (S): (c) and (d) evenness (J'). Schwartz Creek (a). (c): Ford River (b). (d). Bars represent standard errors
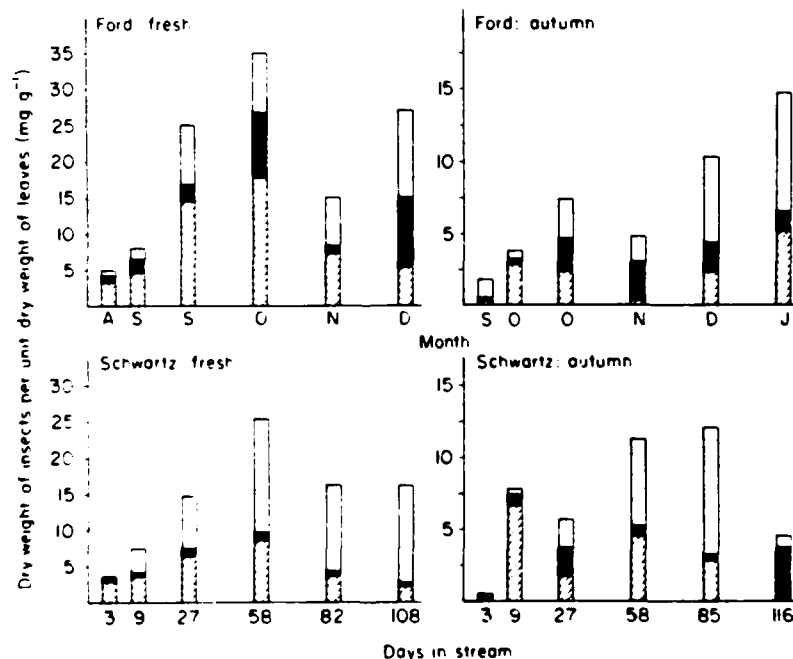


FIG 4 Mean insect biomass (mg dry weight) per unit leaf biomass (g dry weight) on summer fresh and autumn abscissed leaves in the Ford River and Schwartz Creek. Cross-hatched bars: grazer/collectors; black bars shredders, white, black and cross-hatched bars all functional feeding groups, including chironomids Note different y-axes for summer fresh versus autumn abscissed leaves

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autumn leaves in both streams ($t=4.35$, d.f.$=54$, $P<0.001$ for Ford, and $t=2.90$, d.f.$=54$, $P<0.01$ for Schwartz; Fig. 4). Biomass values for two functional feeding groups, shredders and collector/grazers (after Merritt & Cummins, 1984; Appendix 1), were separated from the total insect assemblage. The shredder biomass component was significantly higher on fresh than on autumn leaves in the Ford ($t=2.02$, d.f.$=54$, $P<0.05$); the difference was not significant for the Schwartz samples ($t=0.95$). The collector/grazer biomass (excluding chironomids) was significantly higher on fresh than on autumn leaves in both streams (Ford: $t=4.51$, d.f.$=54$, $P<0.001$; Schwartz: $t=1.80$, d.f.$=54$, $P<0.05$).

## Discussion

The 26-day period when fresh leaves remained relatively intact suggests that they were protected from extensive leaching by an intact cuticle. Once that barrier is broken, they are subject to rapid processing. Alder autumnal leaves have a low C/N ratio (Triska, Sedell & Buckley, 1975), probably owing to the nitrogen-fixing capabilities of the genus. It is possible that the C/N ratio may approach 10:1 in fresh leaves, the optimal ratio for decomposition of organic debris (Alexander, 1961), and thus could contribute to the rapid processing of the leaves after 26 days immersion.

We have no information on leaf chemistry or microbiology for the two leaf treatments, so no strong inferences can be made. However, leaf chemistry may differ seasonally in the same plant (Feeny, 1970; Coley, 1983; Waterman, Mai & McKey 1980; Rosenthal & Janzen, 1979), and chemical changes also occur during abscission (Kramer & Kozlowski, 1979). Such differences between fresh and autumn leaves could produce differential colonization by microorganisms and insects.

In this study, fresh leaves were processed slightly during the first 26 days (assuming that lack of leaf area loss reflects lack of processing). We predicted that the quantity and diversity of insects colonizing those fresh leaves would have been lower than for autumn leaves that were leached and lost weight. Yet, it was during the initial period that fresh leaves supported a quantitatively and/or qualitatively richer insect fauna. In the Ford River, rich-

ness, numbers of individuals and biomass were higher for insects inhabiting fresh versus autumn leaves. However, the additional individuals among families remained the same (no change in $J'$) for both leaf treatments. Most of the differences were quantitative. In Schwartz Creek, neither insect biomass nor total numbers of individuals were different for both treatments; however, the structural community indices ($H'$, $S$ and $J'$) were all significantly higher for insects inhabiting fresh leaves over the initial 26 day period. Thus, fresh leaves in Schwartz Creek supported a qualitatively richer insect fauna than did the autumn leaves.

Unless we were dealing with a qualitatively and quantitatively different insect community (which was not the case for monthly collections of insects in the benthos) in August–September (for fresh leaves) as compared with late September–October (for autumn leaves), we can conclude that the fresh leaves (even though they lost little leaf area) were somehow more 'attractive' substrates. It is possible that fresh leaves support a rich epiphyllic community comprised of fungi, bacteria, algae, protozoa and micrometazoa (after Lock's definition of epilithon, 1981). Rounick & Winterbourn (1983) showed that organic layers of slime, fine particles, bacteria and fungi on stones are potential food sources for stream invertebrates. They also showed that leaf leachates enhanced the biomass of this layer. An organic layer on fresh leaves could be even richer than organic layers developing on stones. A rich epiphyllic community on fresh leaves could account for the simultaneous lack of leaf area loss and for the presence of a more complex insect community than was found on autumn leaves. The higher mass of the collector/grazer functional feeding group could be attributed to the more attractive surfaces of fresh leaves. Certainly, the fresh leaves were 'more slimy' to the touch than were the autumn leaves over the first 26 days of collection. Because fresh leaves were placed in streams the day they were collected, cellular activity may well have continued for a short period after leaves were in the streams. That, coupled with potentially higher nitrogen content and cuticular characteristics of the leaves, may have contributed to the development of an epiphyllic community much richer than that possible on autumn senescent, dry leaves.

Our future work will focus on: (1) the composition and functional role of epiphyllic communities, and (2) the chemical and microbial changes of fresh and autumn leaves over time, to help elucidate the mechanisms for the results obtained in this study. It may be that fresh summer leaf inputs in mid-latitude streams and fresh leaves in tropical heterotrophic streams serve as an important epiphyllic substrate for trophic insect functional feeding groups such as grazers and collectors.

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**Appendix 1.** Insect taxa associated with fresh and autumn leaves on the Ford River and Schwartz Creek based on functional feeding groups (Merritt & Cummins, 1984)

| Functional group | Feeding mechanism and general particle size food range | Taxon | Functional group | Feeding mechanism and general particle size food range | Taxon |
|---|---|---|---|---|---|
| Shredders | Detritivores ($>10^3 \mu$m) | PLECOPTERA | Collectors/ scrapers | Detritivores and herbivores ($<10^3 \mu$m) | EPHEMEROPTERA |
| | | Capniidae | | | Caenidae |
| | | *Paracapnis* sp | | | *Caenis* |
| | | *Capnia* sp | | | Ephemerellidae |
| | | Pteronarcyidae | | | *Ephemerella* |
| | | *Pteronarcys* sp | | | *invaria* |
| | | Taeniopterygidae | | | (Walker) |
| | | *Taeniopteryx* | | | *E. subvaria* |
| | | *nivalis* (Fitch) | | | McDunnough |
| | | TRICHOPTERA | | | Baetidae |
| | | Limnephilidae | | | *Baetis vagans* |
| | | *Anabolia* sp | | | Siphlonuridae |
| | | *Hydatophylax* | | | *Isonychia* sp |
| | | *Pycnopsyche* | | | Leptophlebiidae |
| | | *subfaciata* (Say) | | | *Leptophlebia* sp |
| | | Lepidostomatidae | | | *Paraleptophle-* |
| | | *Lepidostoma* | | | *bia mollis* |
| | | Phryganeidae | | | (Eaton) |
| | | *Ptilostomis* sp | | | Heptageniidae |
| | | DIPTERA | | | *Epeorus vitreus* |
| | | Tipulidae | | | (Walker) |
| | | *Tipula abdomi-* | | | *Stenonema* |
| | | *nalis* (Say) | | | *vicarium* |
| | | | | | (Walker) |
| | | | | | TRICHOPTERA |
| | | | | | Brachycentridae |
| | | | | | *Brachycentrus* sp |
| | | | | | Hydropsychidae |
| | | | | | *Cheumato-* |
| | | | | | *psyche analis* |
| | | | | | (Banks) |
| | | | | | *Hydropsyche* sp |
| | | | | | Polycentropodidae |
| | | | | | *Neureclipsis* sp |
| | | | | | Philopotamidae |
| | | | | | *Chimarra* sp |
| | | | | | *Dolophilodes* sp |
| | | | | | DIPTERA |
| | | | | | Ceratopogonidae |
| | | | | | *Atrichopogon* sp |
| | | | | | Simuliidae |
| | | | | | *Simulium* |
| | | | | | *tuberosum* |
| | | | | | (Lundstr.) |
| | | | | | *Ectemnia* |
| | | | | | *invenusta* |
| | | | | | (Walker) |

Element 7 - Feeding Activity of Grazer Populations

Changes from the Original Synposis -
Experiments conducted heretofore on
Stenonema vicarium did not allow us to
quantify grazing effects from site to site
with the quantitative precision needed to
monitor ELF effects.  Thus, we developed
new techniques in 1985 and abandoned
studies done to this time.

## Objective

The objective of this element is to provide the data
necessary for linking invertebrate herbivores to the
periphyton community based on trophic level analyses.  This
objective includes the determination of the effects of
various levels of herbivory on periphyton community
dynamics.

## Materials and Methods

In 1985, we designed and built small microcosm
streamside flow-through artificial streams for monitoring
effects of grazers on periphyton.  These plexiglass streams
were constructed from 1.27 cm plexiglass and were about 1 m
long with three 15 cm wide channels fed from a common
reservoir.  This reservoir was filled by pumping water from
the Ford River through a 300 micron mesh filter into the
reservoir.  The reservoir also contained polyester fibers as
an additional filter to remove suspended sediments.  This
double filter system proved necessary because of excessive
settling of suspended particles on substrates in its absence.
The pumps were powered by a heavy duty marine battery which
had to be exchanged and recharged daily.  Two of these
streams were constructed so that identical studies could be
conducted at FEX and FCD simultaneously.  However, the 1985
studies were conducted at one site per run as a means of
developing the technique.  In 1986, the simultaneous
experiments will be conducted.

Ceramic tiles (3.6 cm$^2$) were placed in the river 25-30
days prior to experiment initiation for periphyton
colonization.  After this colonization period, the tiles were
placed in the 4 chambers in each channel.  Each chamber was
separated from the next chamber by a plastic screen with mesh
small enough to prevent exchange of grazers between chambers.
These 12 chambers (4 x 3 channels) allowed introduction of
different numbers of grazers (3 levels) in a block design
with up to 4 replications per treatment.  Tiles were taken at
random from each chamber at the end of each experiment for
determination of chlorophyll a (N=8 per chamber), organic
matter biomass (N=8), and cell counts (N=4).

In 1985, we were able to conduct three preliminary
experiments.  In the first experiment, the tiles were all

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covered with sediment on the river bottom at the end of the colonization period. Thus, we conducted colonization experiments with uncolonized tiles in the plexiglass streams. Also, the grazer, Glossosoma nigrior, was unavailable in sufficient quantities at the time of this experiment. Thus, it was conducted with Pycnopsyche at densities of 0, 5, and 15 per chamber primarily as a test of techniques. The second two successful runs were conducted with Glossosoma nigrior (Trichoptera: Glossosomatidae) at densities of 0, 15, and 30 larvae per chamber.

## Results and Discussion

Analyses of the cell count data for the three grazer experiments are still in progress. However, chlorophyll a and biomass analyses have been completed.

In the first experiment, a large Pycnopsyche (guttifer?) was substituted for Glossosoma since not enough Glossosoma were present. The last instar of some species of Pycnosyche are scrapers (Wiggins 1985). Later examination of gut contents of a subsample of Pycnopsyche collected from the Ford River and used in this experiment showed that mostly detrital material was being ingested. There was no significant impact of Pycnopsyche on chlorophyll a levels (Table 7.1). However, presence of Pycnopsyche did have a significant impact on organic matter standing crop (Table 7.1).

In the second experiment at FCD with Glossosoma nigrior, a known grazer (Wiggins 1985), increased grazer density again had no significant effect on chlorophyll a. This same result was observed in the third experiment at FEX (Table 7.2). In both experiments, the presence of 30 grazers had a significant effect on organic matter biomass levels (Table 7.2). Preliminary results from cell counts for experiment two suggested that tiles exposed to grazers showed decreased levels by members of the genus Cocconeis sp. and high abundance by members of the genus Achnanthes.

Results to date, therefore, indicate that grazers have no impact on chlorophyll a levels, alter organic matter ash free dry weight levels, and alter community composition of the periphyton.

## Summary

Techniques have been developed to allow quantification of grazer effects on periphyton community dynamics in the Ford River. These techniques consist of use of streamside plexiglass channels to manipulate grazer densities on pre-colonized ceramic tiles. In the first three experiments conducted in 1985, grazers altered levels of organic matter

measured as ash free dry weight, altered species composition with decreased levels of Cocconeis and increased levels of Achnanthes but had no effect on chlorophyll a levels.

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Table 7.1. A priori Comparison of _Pycnopsyche_ "Grazing" Effects on Chlorophyll a and Organic Matter Biomass Using a Single Classification Model I ANOVA.

### CHLOROPHYLL a

| Source of Variation | df | SS | MS | F | |
|---|---|---|---|---|---|
| Among groups | 2 | 3.213 | 1.661 | 1.684 | ns |
| Control vs. (5+15) Ind. | 1 | 3.318 | 3.318 | 3.362 | * |
| Control vs. 5 Ind. | 1 | 2.602 | 2.602 | 2.636 | ns |
| Control vs. 15 Ind. | 1 | 2.378 | 2.378 | 2.409 | ns |
| 5 Ind. vs. 15 Ind. | 1 | 0.005 | 0.005 | 0.005 | ns |
| Within groups | 93 | 91.773 | 0.987 | | |

### ORGANIC MATTER
### ASH FREE DRY WEIGHT

| Source of Variation | df | SS | MS | F | |
|---|---|---|---|---|---|
| Among groups | 2 | 43.024 | 21.512 | 27.951 | *** |
| Control vs. (5+15) Ind. | 1 | 41.662 | 41.662 | 54.106 | *** |
| Control vs. 5 Ind. | 1 | 25.453 | 25.453 | 33.056 | *** |
| Control vs. 15 Ind. | 1 | 37.982 | 37.982 | 49.327 | *** |
| 5 Ind. vs. 15 Ind. | 1 | 1.361 | 1.361 | 1.767 | ns |
| Within groups | 91 | 70.035 | 0.770 | | |

Table 7.2. A priori Comparison of <u>Glossosoma</u> Grazing Effects on Chlorophyll <u>a</u> and Organic Matter Biomass Using a Single Classification Model I ANOVA.

## EXPERIMENT 2 - FCD

### CHLOROPHYLL <u>a</u>

| Source of Variation | df | SS | MS | F | |
|---|---|---|---|---|---|
| Among groups | 2 | 0.161 | 0.081 | 0.069 | ns |
| Control vs. (15+30) Ind. | 1 | 0.153 | 0.153 | 0.131 | ns |
| Control vs. 15 Ind. | 1 | 0.148 | 0.148 | 0.127 | ns |
| Control vs. 30 Ind. | 1 | 0.086 | 0.086 | 0.074 | ns |
| 5 Ind. vs. 30 Ind. | 1 | 0.008 | 0.008 | 0.007 | ns |
| Within groups | 93 | 108.417 | 1.166 | | |

### ORGANIC MATTER
### ASH FREE DRY WEIGHT

| Source of Variation | df | SS | MS | F | |
|---|---|---|---|---|---|
| Among groups | 2 | 2.517 | 1.259 | 6.279 | ** |
| Control vs. (15+30) Ind. | 1 | 0.363 | 0.363 | 1.814 | ns |
| Control vs. 15 Ind. | 1 | 0.036 | 0.036 | 0.180 | ns |
| Control vs. 30 Ind. | 1 | 1.645 | 1.645 | 8.227 | ** |
| 15 Ind. vs. 30 Ind. | 1 | 2.154 | 2.154 | 10.772 | * |
| Within groups | 90 | 18.039 | 0.200 | | |

## EXPERIMENT 3 - FEX
### CHLOROPHYLL <u>a</u>

| Source of Variation | df | SS | MS | F | |
|---|---|---|---|---|---|
| Among groups | 1 | 1.766 | 1.766 | 2.655 | ns |
| Within groups | 60 | 39.920 | 0.665 | | |

### ORGANIC MATTER
### ASH FREE DRY WEIGHT

| Source of Variation | df | SS | MS | F | |
|---|---|---|---|---|---|
| Among groups | 1 | 19.774 | 19.774 | 21.318 | *** |
| Within groups | 62 | 57.510 | 0.928 | | |

## Element 8 - Fish Community Composition and Abundance

Changes from work plan - Fish community study has been split into a separate element to facilitate analysis. No changes have been made in the actual study plan.

### Objectives

The overall objective of this element is to examine the effects of the Navy's ELF project on the fish community structure and movement in the Ford River. The specific objectives are: 1) To determine and monitor the fish community species composition, structure and relative abundance at both ELF sites; and 2) To determine and monitor the relative mobility of the fish community excluding brook trout in the Ford River.

### Materials and Methods

Two fyke net sites (FCD and FEX) and two weir sites (FCU and TM) were used in this study (Figure 8.1). The two fyke net sites were used in all parts of the study, and the weir sites were operated only for the capture of fish marked at the lower sites for the fish community movement study. Sampling dates for 1983 and 1984 are reported in previous annual reports. Operation of the FCD and FCU sites in 1985 began on May 22 and continued when weather permitted until September 18. The FEX site was in operation from June 17 until September 18 and the TM site was in operation from June 13 until September 18. The number of sample days for each of the sampling years is reported in Table 8.1.

At FCD and FEX, two 1/2 inch bar mesh fyke nets were fished (one facing upstream and one facing downstream). At FCU and TM, a weir constructed of 1/2 inch hardware cloth was used. The weir design was a variation of those used by Hall (1972). All gear was fished continuously when possible, and checked every 24 hours.

All fish were enumerated, measured, and marked by a fin clip distinctive for that site. A subsample of the catch were weighed to provide the necessary data for length-weight relationships. The live fish were then returned to the water upstream or downstream from the station in the direction of travel.

### Results and Discussion

#### A. Species composition

Thirteen species from five orders and ten families were collected at FEX in 1985 (Table 8.2) using 1/2 inch bar mesh fyke nets. This represents a decrease in the number of species from seventeen collected in 1984 although this is still slightly higher than the twelve collected in 1983. No change was seen in the number of orders and families

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FORD RIVER STUDY AREA
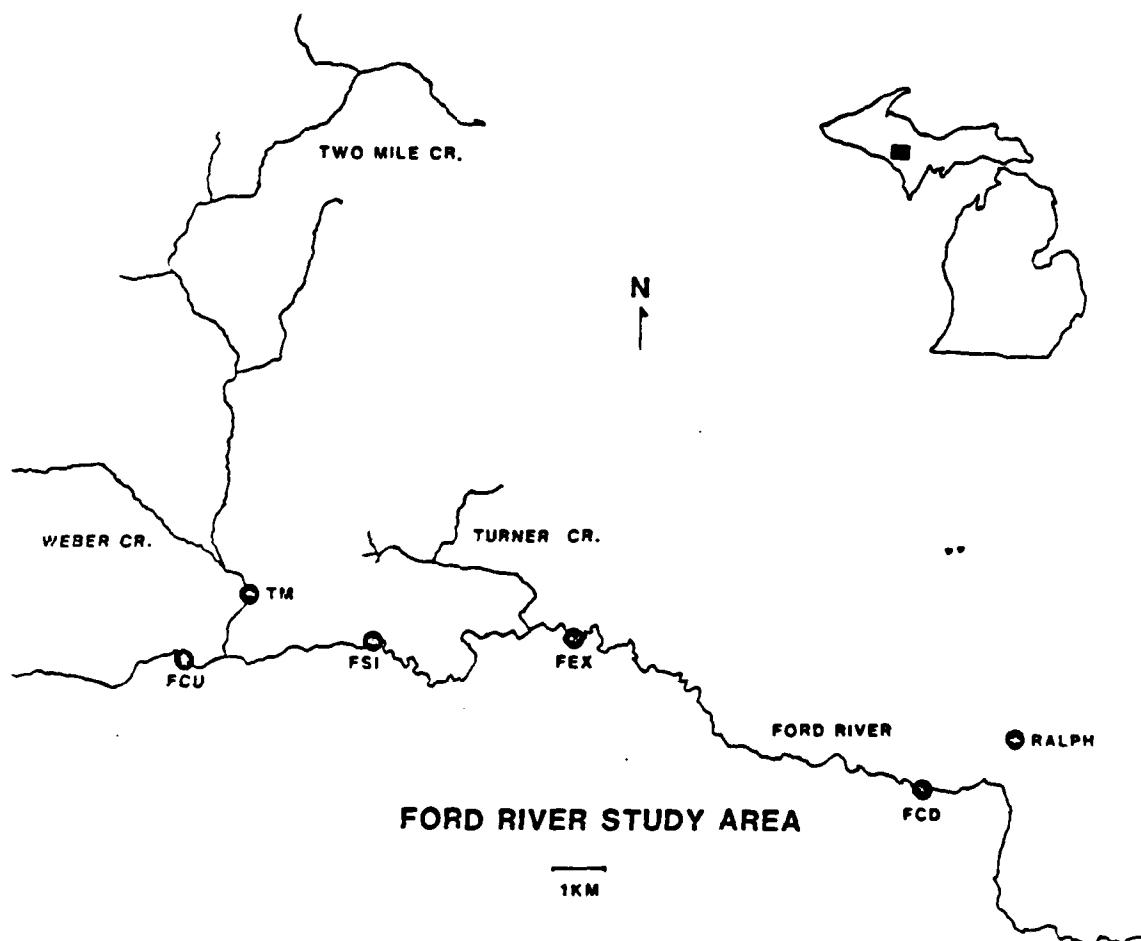
Figure 8.1    Ford River - ELF Fisheries Study Sites

Table 8.1    Number of net-days at each site from 1983-1985

| Site | Year | | |
|------|------|------|------|
|      | 1983 | 1984 | 1985 |
| FCD  | 20   | 93   | 56   |
| FCU  | --   | 47   | 54   |
| FEX  | 20   | 77   | 46   |
| TM   | --   | 122  | 61   |

Table 8.2 Fish species collected at each ELF site from May 1983 to September 1985 using 1/2" mesh fyke nets. Scientific and common names are from Bailey et al. 1970.

| Scientific Name | Common Name | Collection Sites FEX 1983 | FEX 1984 | FEX 1985 | FCD 1983 | FCD 1984 | FCD 1985 |
|---|---|---|---|---|---|---|---|
| **Clupeiformes** | | | | | | | |
| Clupidae | | | | | | | |
| Alosa pseudoharengus (Wilson) | Alewife | | | | | X | |
| **Cypriniformes** | | | | | | | |
| Catostomidae | | | | | | | |
| Catostomus commersoni (Lacepede) | White Sucker | X | | X | X | X | X |
| Hypentelium nigricans (Lesueur) | Northern hog sucker | X | | X | | X | X |
| Cyprinidae | | | | | | | |
| Notropis cornutus (Mitchill) | Common shiner | X | | X | X | X | X |
| Phoxinus eos (Cope) | Northern redbelly dace | X | | | | X | |
| Rhinichthys atratulus (Hermann) | Blacknose dace | X | X | X | X | X | X |
| Rhinichthys cataractae (Valenciennes) | Longnose dace | X | | X | X | X | X |
| Semotilus atromaculatus (Mitchill) | Creek chub | X | | X | X | X | X |
| Semotilus margarita (Cope) | Pearl dace | X | | | | | X |
| **Gadiformes** | | | | | | | |
| Gadidae | | | | | | | |
| Lota lota (Linnaeus) | Burbot | X | | X | X | X | X |
| **Perciformes** | | | | | | | |
| Centrarchidae | | | | | | | |
| Ambloplites rupestris (Rafinesque) | Rock bass | | X | X | X | X | X |
| Lepomis gibbosus (Linnaeus) | Pumpkinseed sunfish | | | | | X | X |
| Micropterus dolomieui (Lacepede) | Smallmouth bass | | X | | | X | X |
| Micropterus salmoides (Lacepede) | Largemouth bass | | X | | | X | X |
| Cottidae | | | | | | | |
| Cottus bairdi (Girard) | Mottled sculpin | X | X | X | X | X | X |
| Percidae | | | | | | | |
| Percina maculata (Girard) | Blacksided darter | X | X | X | X | X | X |

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| Scientific Name | Common Name | Collection Sites | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- |
| | | FEX | | | FCD | | |
| | | 1983 | 1984 | 1985 | 1983 | 1984 | 1985 |
| Petromyzontiformes | | | | | | | |
| Petromyzontidae | | | | | | | |
| Ichthymyzon fossor (Reighard and Cummins) | Northern brook Lamprey | | X | | | | |
| Petromyzon marinus (Linnaeus) | Sea Lamprey | | X | X | X | X | X |
| Salmoniformes | | | | | | | |
| Esocidae | | | | | | | |
| Esox lucius (Linnaeus) | Northern pike | X | X | X | X | X | X |
| Salmonidae | | | | | | | |
| Salvelinus fontinalis (Mitchill) | Brook trout | X | X | X | X | X | X |
| Umbridae | | | | | | | |
| Umbra limi (Kirtland) | Central mudminnow | X | X | X | X | X | X |
| Siluriformes | | | | | | | |
| Ictaluridae | | | | | | | |
| Ictalurus nebulosus (Lesueur) | Brown bullhead | | | | | | X |

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collected in 1985 from 1984. The 1983 sampling collected only four orders and eight families of fish. The loss in species collected in 1985 was entirely of rare species that occurred in low numbers.

The catch at FCD in 1985 consisted of seventeen species from six orders and eleven families (Table 8.2). This represents no change in numbers of species or orders from previous years. One additional family was collected in 1985 than the previous years. Again, as in the FEX samples, the only changes in the species composition occurred in the rare species which occur in low numbers.

The species composition was consistantly higher at FCD than at FEX in numbers of species, families and orders. This can attributed to the differences in habitat heterogenity such as the increase in pool habitats at FCD, and the location of FCD which is closer to a large marsh-warmwater area and to Lake Michigan. All of the differences in the community composition between the sites were in the uncommon species, thus overall the two sites were similiar in the species composition.

## B. Species abundance

The fish community at FEX was dominanted by six species (Table 8.3) with the majority of individuals caught from the cyprinid family. Overall, the species structure was stable during the period from 1983 to 1985 with common shiners and brook trout demonstrating the greatest stability in percent catch. Burbot and creek chubs showed the greatest fluctuations in their relative abundance which may be attributed to possible instability in their respective year-class strengths or changes in their suspectibility to our gear. Overall, the community at FEX was stable in relative abundance with creek chubs and common shiner being the dominant two species.

The relative abundance of the catch at FCD was dominated by the same species as at FEX with the majority of the catch from the cyprinid family (Table 8.3). Most species demonstrated a stable relative abundance for the period from 1983-1985, only the white sucker and the burbot showed any large amount of fluctuation in their numbers. The changes in white sucker percent catch can be attributed to our sampling of their spawning run in 1984 and not in other sampling years. Burbot changes in percent catch may be attributed to variability in their respective year-class strengths. FCD consistantly showed higher percent catches of common shiners and lower percent catches of burbot than FEX. These differences are probably caused by the differences in the available habitat for these two species at the two sites. There were also higher catches of other species at FCD which again reflects the differences in habitat and relative watershed location of the two sites.

Another indication of the relative stability of the fish communities at the two sites is reflected in the mean

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Table 8.3 Percent catch of the dominant fish species at each ELF site from May 1983 to September 1985 using 1/2" mesh fyke nets.

| Species | Year | | | |
|---|---|---|---|---|
| | 1983 | 1984 | 1985 | Combined |

FEX

| Species | 1983 | 1984 | 1985 | Combined |
|---|---|---|---|---|
| White sucker | 8.8 | 8.6 | 5.6 | 7.7 ± 1.8 |
| Burbot | 20.1 | 24.1 | 12.9 | 19.3 ± 6.0 |
| Longnose dace | 8.4 | 7.9 | 2.9 | 6.4 ± 3.0 |
| Creek chub | 22.7 | 16.6 | 33.3 | 24.2 ± 8.4 |
| Common shiner | 23.0 | 27.1 | 24.7 | 24.9 ± 2.1 |
| Brook trout | 12.3 | 10.2 | 16.0 | 12.8 ± 2.9 |
| Other species | 4.6 | 5.3 | 4.6 | 4.8 ± 0.4 |

FCD

| Species | 1983 | 1984 | 1985 | Combined |
|---|---|---|---|---|
| White sucker | 5.5 | 13.1 | 7.6 | 8.7 ± 3.9 |
| Burbot | 17.0 | 6.0 | 8.3 | 10.4 ± 5.8 |
| Longnose dace | 4.6 | 4.5 | 1.2 | 3.4 ± 1.9 |
| Creek chub | 21.1 | 25.4 | 26.2 | 24.2 ± 2.7 |
| Common shiner | 33.9 | 35.6 | 38.6 | 36.0 ± 2.4 |
| Brook trout | 13.8 | 11.3 | 10.6 | 11.9 ± 1.7 |
| Other species | 4.0 | 3.6 | 7.5 | 5.0 ± 2.1 |

Shannon-Weiner index values (Table 8.4). No significant differences were detected between years within a site (Kruskal-Wallis Test, p>0.05) or between sites in index values (Mann-Whitney U Test, p>0.05). FEX did generally have higher index values and this was probably caused by larger pulses in catches from spawning migrations seen at FCD. Overall, the fish community structure was stable from year to year and between the two ELF sites.

## C. Catch statistics

Catch rates. Catch rates for the dominant fish species as represented by mean daily catch are summarized in Table 8.5.

White sucker catch rates showed no significant differences (TTest, p>0.05) in mean catch between years within a site although catches did appear to decrease at FEX. There was no significant differences in mean catch detected between sites (TTest, p>0.05). The large standard deviations seen for this species represents two pulses of catches for this species, the first pulse is a spawning migration in May- early June and the second pulse is a downstream pulse of lake bound juveniles in August- early September.

Burbot catch rates showed a decrease from 1983 to 1985 at both sites which was significant at FEX (1983+1984''> 1985, Paired TTests, p<0.05) and at FCD (1983>1984, Paired TTests, p<0.05). Catch rates were significantly higher at FEX in 1983 (TTest, p<0.05) and displayed generally higher catches in 1984 and 1985 than at FCD, which is indicative of the better burbot habitat at FEX. The standard deviation for burbot reflects a catch pulse in June- early July which may be caused by increasing water temperatures to above optimial for burbot thus these fish are moving to areas of cooler water temperatures.

Longnose dace catch rates were low at both sites and were decreasing from 1983-1985 although this trend was not significant (Paired TTests, p>0.05). No significant differences were found between sites within years (TTest, p>0.05). The variance in this data is indicative of the schooling nature of this fish along with the spring spawning migration and may also reflect the poor recruitment of this species to our gear because of their small body size and body shape.

Creek chub catch rates showed a significant decline at FEX in 1984 from 1983 and 1985 rates (TTest, p<0.05). FCD creek chub catch rates were generally higher and showed the opposite trend with the peak in catch rates seen in 1984. No significant differences were found between sites in creek chub catch rates (TTest, p>0.05). The high standard deviations for this species reflects the spring spawning migration pulse in May- June.

Decreasing catch rates were seen for common shiners at FEX from 1983 to 1985 although this trend was not statistically significant (Paired TTests, p>0.05). FCD catch

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Table 8.4  Mean daily Shannon-Wiener diversity index values for FEX and FCD from 1983-1985.

| Year | Site | |
| --- | --- | --- |
| | FEX | FCD |
| 1983 | 2.16 ± 0.26 | 1.94 ± 0.36 |
| 1984 | 2.20 ± 0.56 | 2.03 ± 0.33 |
| 1985 | 1.97 ± 0.39 | 2.15 ± 0.33 |

Table 8.5    Mean daily catch ± 1 standard deviation for the
             dominant fish species at each ELF site from May 1983
             to September 1985 using 1/2" mesh fyke nets.

| Species | Year | | |
|---|---|---|---|
| | 1983 | 1984 | 1985 |
| FEX | | | |
| White sucker | 3.1 ± 3.8 | 1.9 ± 4.0 | 0.9 ± 2.9 |
| Burbot | 7.0 ± 6.6 | 5.2 ± 6.4 | 2.0 ± 3.3 |
| Longnose dace | 2.9 ± 3.8 | 1.7 ± 3.2 | 0.5 ± 0.9 |
| Creek chub | 7.9 ± 7.8 | 3.6 ± 5.5 | 5.2 ± 7.1 |
| Common shiner | 8.0 ± 10.1 | 5.9 ± 6.6 | 3.9 ± 5.8 |
| Brook trout | 4.3 ± 9.1 | 2.2 ± 2.7 | 2.5 ± 3.5 |
| Other species | 1.6 ± 2.6 | 1.1 ± 1.4 | 0.7 ± 1.5 |
| FCD | | | |
| White sucker | 1.5 ± 1.9 | 3.9 ± 16.4 | 2.0 ± 3.1 |
| Burbot | 4.6 ± 3.7 | 1.8 ± 2.1 | 2.1 ± 2.3 |
| Longnose dace | 1.2 ± 2.1 | 1.3 ± 2.5 | 0.3 ± 0.7 |
| Creek chub | 5.8 ± 10.1 | 7.6 ± 18.9 | 6.7 ± 8.0 |
| Common shiner | 9.3 ± 10.0 | 10.7 ± 13.3 | 9.9 ± 11.2 |
| Brook trout | 3.8 ± 6.9 | 3.4 ± 5.9 | 2.7 ± 4.2 |
| Other species | 1.1 ± 1.3 | 1.1 ± 1.6 | 1.9 ± 2.0 |

rates were stable for this species through this period and were significantly higher in 1984 and 1985 than those found at FEX (TTest, p<0.05). Spawning migrations in June- July were the main cause of the high standard deviations at both sites.

No trends were seen at either site in brook trout catch rates. The absense of any trend along with the high standard deviations are reflective of the temperature related movement in June-July of brook trout from both sites to headwater areas. This movement will be discussed in detail in element 9.

In summary, catch rates and trends were similiar at both sites for most species. The catch rates were higher for burbot at FEX and higher for common shiners at FCD. Other species displayed similiar catch rates at both sites.

Catch length. Mean length data is summarized for each year in Table 8.6.

White sucker length data showed similiar trends at both sites over the period from 1983 to 1985. Data for 1984 showed significantly larger fish than in 1983 or 1985 at both sites which can be attributed to the pulse of spawning lake fish which are considerably larger than the stream resident fish. Fish from FCD were significantly larger than those from FEX in 1984. No other differences between sites were significant (TTest, p>0.05).

Burbot length data demonstrated a slight increase in mean length at both sites from 1983 to 1985 which was statistically significant at FCD (Paired TTests, p<0.05). Overall, no differences were found between sites in mean length except for 1985 when the mean length was greater at FCD (TTest, p<0.05). The overall increase in size may be attributed to a decrease in densities as seen in catch rates.

Mean longnose dace length was greater at FCD than FEX although this trend was only statistically significant for 1983 (TTest, p<0.05). The lack of any consistant trend in length may be caused by selectivity of our gear for larger individuals of this species thus a small length range of fish to test statistically. No trends in size were seen at FEX although a significant trend toward decreasing size was seen at FCD during the 1983-1985 sampling period (Paired TTests, p<0.05).

Generally, larger creek chubs were collected at FCD than FEX during 1983-1985 with this data being significant for 1983 and 1984 (TTest, p<0.05). This can be attributed to the larger fish during the spring spawning migration at FCD than FEX which probably come upstream from the large pool-marsh area below this site to spawn. Smaller fish were collected at both sites in 1985 than in the previous years with this trend being significant at FCD (Paired TTests, p<0.05).

Common shiner mean length was also significantly larger at FCD than FEX in 1983 and 1984 (TTest, p<0.05). No trends were seen in mean length at either site for the 1983 to 1985 sampling period.

Brook trout mean length was significantly greater at FCD

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Table 8.6  Mean length (mm) ± 1 standard deviation for the dominant fish species at each ELF site by year for 1983-1985 using 1/2" mesh fyke nets.  Sample size is in parentheses.

| Species | Year | | |
|---|---|---|---|
| | 1983 | 1984 | 1985 |
| **FEX** | | | |
| White sucker | 170.7 ± 64.7 (62) | 236.0 ± 102.6 (137) | 135.2 ± 65.7 (41) |
| Burbot | 164.3 ± 33.3 (141) | 165.7 ± 28.1 (319) | 171.5 ± 29.6 (90) |
| Longnose dace | 104.8 ± 12.3 (58) | 110.8 ± 9.9 (67) | 103.1 ± 10.5 (17) |
| Creek chub | 134.9 ± 32.5 (158) | 142.1 ± 32.0 (223) | 128.4 ± 28.3 (207) |
| Common shiner | 113.4 ± 17.4 (160) | 108.8 ± 15.6 (364) | 112.1 ± 21.6 (160) |
| Brook trout | 195.9 ± 52.4 (86) | 191.1 ± 64.9 (155) | 226.1 ± 66.3 (123) |
| **FCD** | | | |
| White sucker | 160.9 ± 54.6 (30) | 303.5 ± 103.8 (267) | 133.3 ± 54.7 (99) |
| Burbot | 166.4 ± 36.7 (93) | 164.7 ± 29.7 (54) | 180.8 ± 30.0 (111) |
| Longnose dace | 114.2 ± 9.2 (21) | 108.6 ± 10.8 (56) | 99.8 ± 25.0 (16) |
| Creek chub | 153.5 ± 33.1 (122) | 150.7 ± 32.9 (490) | 129.1 ± 28.3 (352) |
| Common shiner | 122.5 ± 19.3 (183) | 111.8 ± 18.9 (668) | 116.5 ± 53.4 (511) |
| Brook trout | 192.0 ± 38.9 (76) | 231.5 ± 53.8 (308) | 227.0 ± 56.0 (150) |

then FEX in 1984 (TTest, p<0.05) with no other differences detected. Mean length did increase at both sites from 190-195 mm to 220-230mm from 1983 to 1985 which is typical of a fish population which has a fluctuating year-class tendencies. The increase in mean length reflects a dominant year class moving through the population.

In summary, both sites had a similiar size structure for white suckers, burbot, and brook trout. Longnose dace, common shiners and creek chubs were generally larger at FCD. Both sites showed similiar trends in size structure.

## D. Fish Community Mobility

Most non-salmonid species with adequate sample sizes demonstrated site to site movement as shown by the approximately 20% recapture rate at other sites than the marking site (Table 8.7). Although fewer fish were marked in 1985 for common shiners, creek chubs and burbot than 1984, recapture percentages at sites other than the marking site were consistant from year to year. Low sample sizes for white suckers, longnose dace and northern pike were probably responsible for the lack of movement seen for these species in 1985. In summary, the Ford River fish community has a consistant measurable mobile component for the non-salmonid species which will be monitored for the effects of the ELF project.

## Future Analysis

Some extensions of our community study which are being performed and will be discussed in future reports include: 1) An analysis of fish community size structure using seasonal length frequency data; 2) An age and growth analysis of creek chubs, common shiners, longnose dace and mottled sculpins; and 3) A burbot movement study using individually freeze branded fish since past attempts with tags were unsuccessful.

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Table 8.7 Recapture data summary for all dominant species except brook trout from FEX and FCD for 1984 and 1985.

| Species | Total Marked | Number Recaptured | % Recapture by Location | | | |
|---|---|---|---|---|---|---|
| | | | At Marking Site | Upstream 1 Site | Downstream 1 Site | Upstream 2 Sites |
| **1984** | | | | | | |
| White sucker | 405 | 15 | 86.6 | 6.7 | | 6.7 |
| Common shiner | 1084 | 122 | 79.5 | 11.5 | 9.0 | |
| Creek chub | 700 | 72 | 81.9 | 12.5 | 5.6 | |
| Longnose dace | 110 | 22 | 72.8 | 13.6 | 13.6 | |
| Burbot | 405 | 15 | 86.6 | 6.7 | 6.7 | |
| Northern Pike | 13 | 5 | 20.0 | 40.0 | 40.0 | |
| **1985** | | | | | | |
| White sucker | 125 | 2 | 100.0 | | | |
| Common shiner | 622 | 63 | 77.8 | 9.5 | 9.5 | 3.2 |
| Creek chub | 520 | 28 | 82.1 | 14.3 | | 3.6 |
| Longnose dace | 20 | 1 | 100.0 | | | |
| Burbot | 170 | 22 | 86.3 | 4.5 | 9.2 | |
| Northern Pike | 5 | 0 | | | | |

Element 9 - Brook Trout Movement

Changes from the work plan - Brook trout study has been split off from the fish community section to facilitate analysis. No other changes have been made in the work plan.

Objectives

The overall objective of this element is to examine the effects of the Navy's ELF project on brook trout (Salvelinus fontinalis). Brook trout are well known to be sensitive to thermal changes and appear to move to avoid suboptimal conditions in the Ford River as shown previously. Any changes by ELF could cause severe physiological problems for the fish. The specific objectives of this element are: 1) To determine the seasonal pattern and magnitude of brook trout movement thru the ELF corridor; 2) To determine the rates of movement thru the ELF corridor of brook trout; and 3) To determine the mechanism for these movements.

Materials and Methods

The sites and gear used in this element were previously described in element 8. All brook trout were removed on a daily basis from the traps and anesthetized with MS-222 to reduce handling stress at a 500 mg/l dosage as recommended by Meister and Ritzi (1958), and Schoettger and Julin (1967) for hard water applications. All brook trout were then enumerated, measured, and weighed. Fish greater than 190 mm were tagged with either a streamer tag or a monofilament attached disc tag that were individually numbered. All fish received a site specific fin clip, and if tagged an adipose fin clip to examine tag loss. All fish after a recovery period were released upstream or downstream from the site in the direction of travel.

Data analysis examining the role of physical and chemical factors on brook trout movement at FCD was done using ambient monitoring data. Physical and chemical data at FCU and TM was collected by the fisheries staff in 1984 and 1985. Flow was calculated from a calibrated staff gauge at both FCU and FCD on a daily basis. Temperature data was collected continuously using both a thermograph and a calibrated max-min thermometer at TM and FCU. Chemical data (DO, pH and alkalinity) was collected a on bi-weekly basis at TM and FCU using standard methods.

Results and Discussion

A. Marking Statistics

A total of 314 fish were tagged in 1984 and 124 fish were tagged in 1985 (Table 9.1). The between site tag recapture rate was consistant between years at 16.7% in 1984 and 14.3% in 1985. The estimated tagging mortality was 5.6%

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Table 9.1 Brook trout marking and recapture summary for FEX and FCD for 1984 and 1985.

| Year | Tag Summary | Site | |
|---|---|---|---|
| | | FEX | FCD |
| 1984 | Number Tagged | 71 | 243 |
| | Number Fin Clipped | | |
| | (<190 mm) | 45 | 30 |
| | (>190 mm) | 4 | 7 |
| | Percent Tag Recapture | 16.7% | |
| | Estimated Tagging Mortality | 5.7% | |
| | Percent Angler Recapture | 12.1% | |
| 1985 | Number Tagged | 45 | 81 |
| | Number Fin Clipped | | |
| | (<190 mm) | 24 | 31 |
| | (>190 mm) | 14 | 22 |
| | Percent Tag Recapture | 14.3% | |
| | Estimated Tagging Mortality | 8.7% | |
| | Percent Angler Recapture | 3.0% | |

in 1984 and 8.7% in 1985 which is probably an underestimate because we are only examining fish which float back into our nets and fish that we visually find on our regular searches. The increase in the 1985 tagging mortality was caused by a bacterial infection at FEX in the first week of July. The percentage of angler returns was 12.1% in 1984 and 3.0% in 1985 which is an underestimate by approximately 66% from angler interviews.

Tag retention was close to 100% for the first month, then declined to total tag loss by the fifth month. This indicates that, although this is an appropriate technique for our short term movements, we need to increase our tag retention time to maximize the data return. We will try freeze branding and small opercular tags in the 1986 sampling season to increase individual mark retention.

### B. Brook Trout Catch Patterns

Brook trout catches peaked in the spring- early summer at all sites except FCU. Since catch patterns were similar at all sites, data from FCD will be presented as example data in this report (Figures 9.1 and 9.2). In 1984, daily catch was at its maximum in the first week of June at 15.8 brook trout collected per day with high catch rates continuing for three weeks. A similar catch pattern was seen in 1985 although delayed by one month until the first week of July when 11.7 brook trout were collected per day and continued for only an one week period. Catch rates decrease rapidly after this week to between 0-1 fish per day. Movement in the upstream direction was significantly higher than the downstream direction in both years at all sites (Mann-Whitney U Test, $p < 0.05$). In summary, the brook trout showed a consistant upstream movement pattern at all sites in the spring- early summer of both sampling years although the intensity and timing varied between the years.

To determine the mechanism(s) responsible for this movement, relationships were examined between brook trout catch rates, and discharge, solar radiation, water temperature and pH using nonparametric correlation analysis (Spearman rank correlation, $p < 0.05$). Dissolved oxygen was ruled out as a possible mechanism as values are generally at or near saturation and above 7 mg/l all year. No significant correlations were found between brook trout catch and the above variables using the entire data set from each year ($p > 0.05$). However, when a graphical analysis is used mean water temperature is indicated as the major mechanism. When mean water temperatures increase to above 16C then the brook trout catches increase to their maximum and continue at a high rate in both years as long as temperatures remain above 16C (Figure 9.3). This corresponds to the upper limit of the optimal growth temperatures in the literature for brook trout which range from 13 - 16 C (Baldwin 1956, McCormick et al. 1972, and Hokanson et al. 1973). Thus, brook trout movement in the Ford River appears to be based on optimal growth temperatures which are approximately 2 C lower than the final

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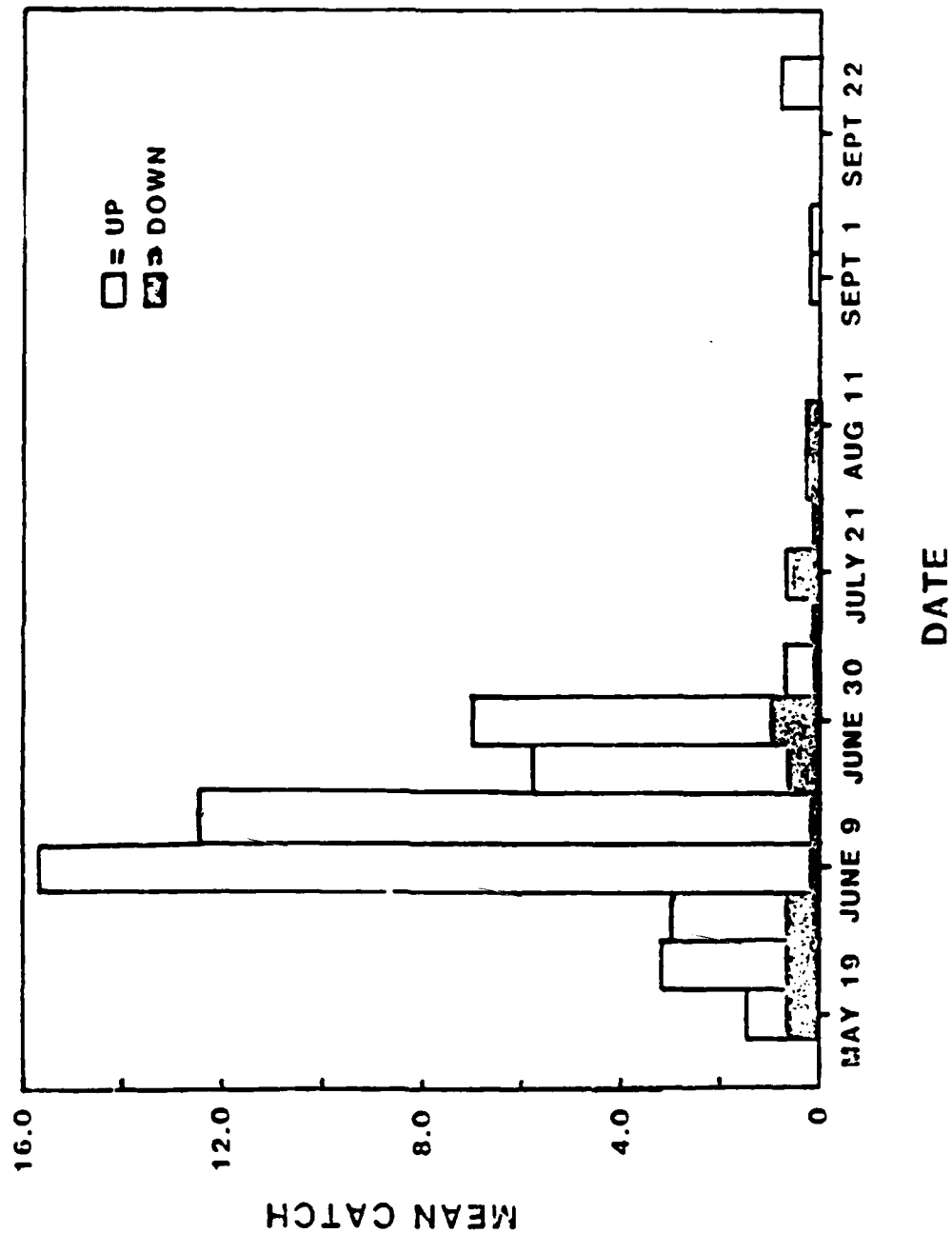
Figure 9.1  Mean daily catch of brook trout calculated on a weekly basis at FCD in 1984. Open bar areas refer to upstream moving catch and closed bar areas refer to downstream moving catch. Bars reflect actual catch not percent catch.
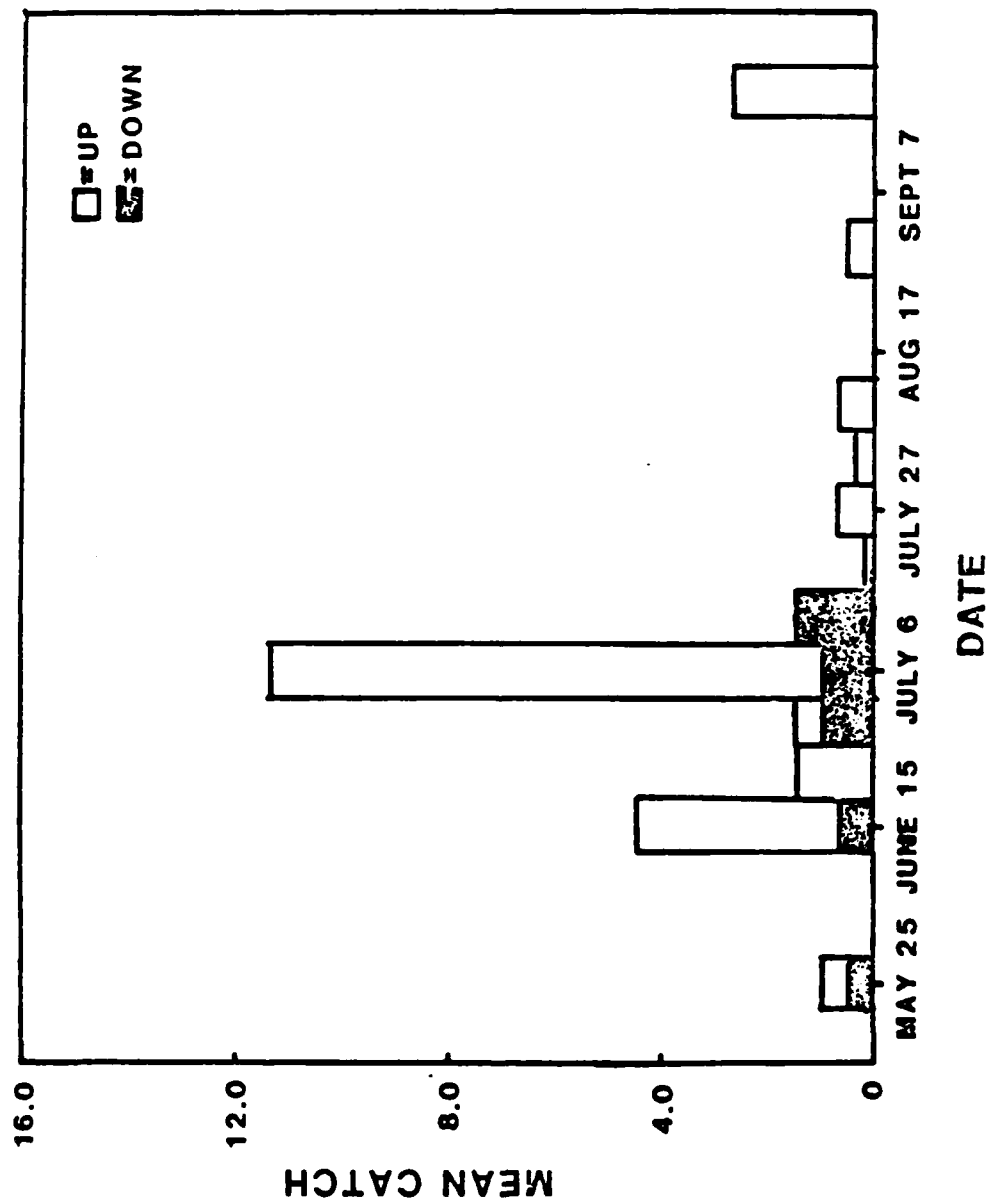
Figure 9.2 Mean daily catch of brook trout calculated on a weekly basis at FCD in 1985. Open bar areas refer to upstream moving catch and closed bar areas refer to downstream moving catch. Bars reflect actual catch not percent catch.
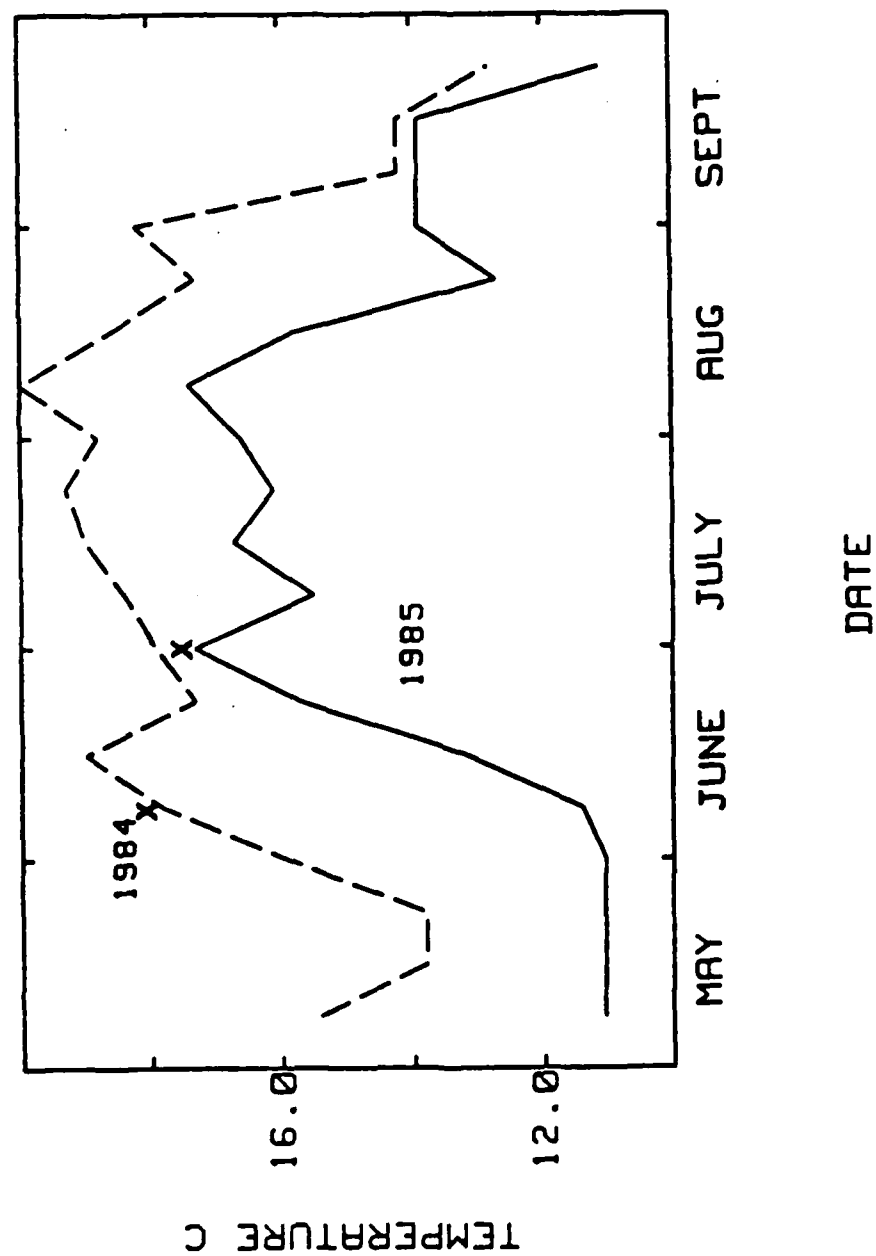
Figure 9.3   Mean daily temperature (C) calculated on a weekly basis at FCD in 1984 and 1985. X symbols on figure show when mean daily brook trout catch was at its maximum.

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preferum temperatures of from 16-19 C (Sullivan and Fisher 1953, Javaid and Anderson 1967, Peterson 1973, Cherry et al. 1975, Cherry et al. 1977, and Muller 1977) and approximately 4-9 C less than lethal temperatures of from 20.1 to 25.3 C (Fry et al. 1946, McCormick et al. 1972, and Cherry et al. 1977). This mechanism also appeared to be responsible for the decreased duration and intensity of movements in the 1985 sampling season because mean temperatures declined below 16 C in the second week of July and remained below this temperature for the rest of the year, thus the brook trout were able to remain at optimal growth temperatures at the lower sites.

### C. Brook Trout Movement Characteristics
The brook trout movement was found to be from the FEX and FCD sites upstream to the TM site on Two Mile Creek based on both gear recapture and usuable angler return data (Table 9.2). Only one fish was recaptured at FCU during the two sampling seasons. No downstream movement from Two Mile Creek was found thru November in 1984 and thru September in 1985. Three tag loss fish from the TM site in 1984 were collected in 1985 at FCD, thus some return movements occur between the winter and early spring. The length of the brook trout that made this movement was significantly greater than 190 mm with only six clipped fish under 190 mm captured at TM in 1984 and no clipped fish under 190mm were collected in 1985 (Chi-Square Test, $p < 0.05$).

Optimal growth temperatures also appeared to be responsible for the movement up Two Mile Creek instead of continuing up the Ford River. Mean temperatures as shown in figure 9.4 rose above 16 C at FCU before the peak movement period and remained above that temperature throughout 1985. Mean temperatures never rose above 16 C at TM in either 1984 or 1985. Thus, brook trout "chose" the tributary that they could maintain optimal growth in.

### D. Brook Trout Movement Rates
Brook trout were found the to move at mean rates of between 1.1 to 5.0 km/day (Table 9.2). Fish moving from FEX to TM (12.7 km) moved at similiar rates from 1.4 to 1.6 km/day in 1984 and 1985. Movement from FCD to TM (26.8 km) occurred at different mean rates in 1984 (2.9 km/day) than in 1985 (5.0 km/day). Brook trout that were moving between FCD and FEX (14.1 km) also moved at different rates in the two sample years with rates of 2.7 km/day in 1984 and 1.2 km/day in 1985. Angler tag return data from throughout the Ford River verified the above trends and indicated that brook trout move at a steady rate (1984 - 2.4 km/day, 1985 - 1.1 km/day) upstream similiar to rates recorded from our sampling gear. The differences in movement rates between years will be analyzed further and reported on in a future report.

### E. Literature Comparisons
Brook trout have been characterized in to show little

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Table 9.2 Brook trout movement rate summary for 1984 and 1985.

| Year | Recapture Type | Site Marked to Site Recaptured | Distance (km) | N | Mean Rate (km/day ± 1SD) | Mode (km/day) |
|---|---|---|---|---|---|---|
| 1984 | Recaptured Fish | | | | | |
| | | FEX - TM | 12.7 | 11 | 1.4 ± 0.9 | 1.2 |
| | | FCD - TM | 26.8 | 39 | 2.9 ± 1.7 | 2.5 |
| | | FCD - FEX | 14.1 | 7 | 2.7 ± 1.6 | 2.0 |
| | Angler Returns | | | | | |
| | | FEX | 7.0 | 1 | 2.5 | |
| | | FCD | 14.4 ± 9.0 | 18 | 2.4 ± 2.6 | 1.3 |
| 1985 | Recaptured Fish | | | | | |
| | | FEX - TM | 12.7 | 7 | 1.6 ± 0.9 | 1.1 |
| | | FCD - TM | 26.8 | 6 | 5.0 ± 3.2 | 4.2 |
| | | FCD - FEX | 14.1 | 3 | 1.2 ± 0.3 | 1.3 |
| | Angler Returns | | | | | |
| | | FCD | 8.7 ± 9.9 | 3 | 1.1 ± 1.1 | 1.0 |

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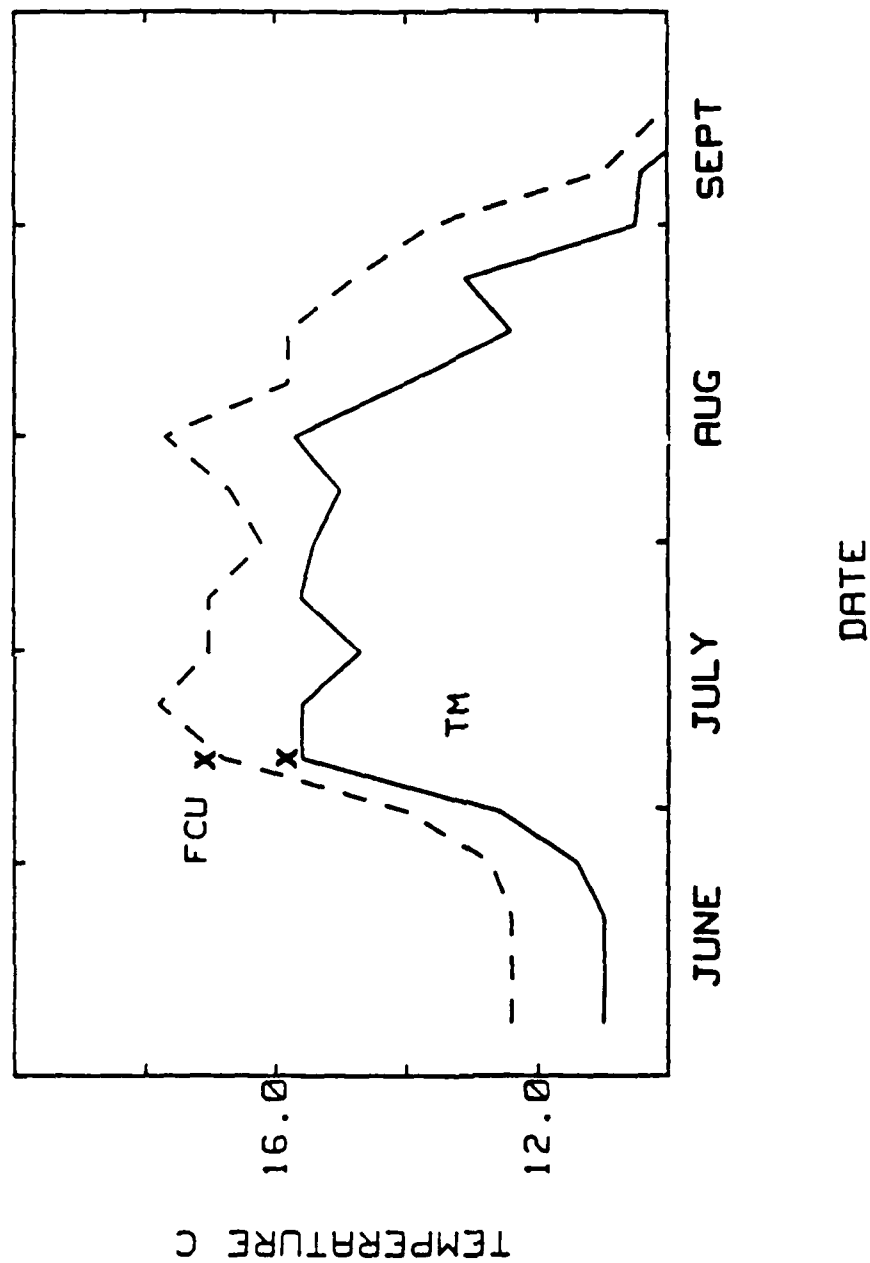
Figure 9.4    Mean daily temperature (C) calculated on a weekly basis at TM and FCU in 1985. X symbols on figure show when mean daily brook trout was at its maximum at FEX and FCD.

or no movement in studies by Holton (1953) and Shetter (1968). Flick and Webster (1975) did find some spring and fall movements (6.6 km) but gave no reasons for this movements or any movement rates. The lack of long distance movement in the literature may be a product of the "good" trout streams the studies are conducted on. The Ford River is considered a marginal brook trout stream by Michigan DNR (D. Siler, personal comm.) because of its low densities of brook trout. Thus, brook trout movement in response to suboptimal temperatures on a thermally unstable stream like the Ford River is a critial environmental parameter to examine for the effects of the ELF project since magnetic cues have been shown to be used by sockeye salmon (Quinn and Brannon 1982). Disorientation or movement in the "wrong" direction may have severe affects on the fish.

## Future Investigations

New analyses of the Ford River ELF study brook trout population that will be reported on in future reports include: 1) An age and growth analysis; 2) Population analysis in conjunction with MI DNR of five sections of the Ford River which will also allow us to determine what percentage of the population is moving; and 3) A habitat analysis of young of the year fish with particular interest in the use of groundwater inputs.

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Element 10 - <u>Parasite Loads of Selected Fish Species</u>

Changes from Work Plan - Selected fish species are the
longnose dace, <u>Rhinichthys</u>
<u>cataractae</u> (Family: Cyprinidae)
and mottled sculpin, <u>Cottus</u> <u>bairdi</u>
(Family: Cottidae).

Objectives

The overall objective is to examine the effects of low
level, long term electromagnetic fields and gradients on
the parasite faunas of longnose dace and mottled sculpins.
Fish parasites can be used as indicators of stress and can
integrate the habitats used by fish, fish-invertebrate
interactions, and abiotic factors. The specific objectives
are: 1) To establish a taxonomic base of parasitic
species that infect longnose dace and mottled sculpins.
2) To calculate the infection rates (prevalence and mean
number) of parasites of these two fish species collected at
each site. 3) To statistically analyze the data to
determine if relationships exist between parasite infection
rates and fish sex, age (length), as well as to determine
if differences in parasite infection rates exist between
sites, seasons.

Material and Methods

Five hundred-fifteen mottled sculpins (108 from FCU,
208 from FEX, 199 from FCD) were collected by kick sampling
with a 1/8" mesh minnow seine and fyke netting from May
1983 through November 1984. Eight hundred seventy-eight
longnose dace (197 from FCU, 340 from FEX, 341 from FCD)
were also collected from May 1983 through October 1985. At
the collecting site, fishes were killed in 10% formalin; a
slit was then made from the vent anteriad to the isthmus
area of the fish to preserve the viscera. After this,
fishes were preserved in 10% formalin, individually
packaged by Kapak heat sealable pouches, and sent to MSU.

At necropsy, a fish specimen accession number was
formulated and the weight, total length, and sex of each
fish were recorded and scales or otoliths were taken for
age determination. Fishes were examined for external
parasites before the abdominal cavity was opened. The
eyes, brain, gills, liver, gall bladder, kidney, urinary
bladder, gonads, and the digestive tract were placed in
petri dishes and examined with a dissecting microscope
and/or compound microscope.

Trematodes and cestodes recovered were processed by several techniques and stained with Mayer's Alum Carmine, Grenacher's Alcoholic Borax-Carmine, and Lynch's Precipitated Method using Grenacher's Alcoholic Borax-Carmine (Meyer and Penner, 1958). Nematodes were cleared in glycerin and examined in temporary mounts. Parasites were identified to genus according to Hoffman (1967), Schell (1970), Schmidt (1970), and Yamaguti (1961, 1963, 1971). Species were determined, wherever possible by reference to the original description within a genus. The project thanks Dr. Charles R. Peebles, Department of Natural Science, MSU, for his help in identifying some of the parasites.

Prevalence is the percentage of fish infected and mean number is the mean number of worms per infected fish in a given sample. The prevalence and/or mean number of each parasite species occurring in sculpins and dace were calculated by sex. However, because of nonsignificant differences in prevalence and mean number for the parasite species, the parasitological data were combined, irrespective of host sex. The prevalence and/or mean number of each parasite species from sculpins and dace were graphed monthly at each site to identify seasonal trends. Since trends were not apparent and due to the extreme variation in monthly mean numbers, monthly parasite data were combined into spring, summer, fall, and winter. Chi-square analysis, Kruskall-Wallis Test, and the Mann-Whitney U Test were used to determine if the prevalence and/or mean number of each parasite species significantly differed between fish sex, site, and season.

## Results and Discussion - Mottled Sculpins

The parasite fauna of mottled sculpins from FCU, FEX, and FCD are in Tables 10.1, 10.2, and 10.3. Overall, 510 (99%) of the 515 sculpins examined were infected with at least one parasite species. Twelve parasite species (1 Monogenea, 5 Digenea, 1 Cestoda, 2 Nematoda, 3 Protozoa) were recovered. Gyrodactylus bairdi, Epistylis sp., and Trichodina sp. infected the gills, while Myxobolus sp. occurred in the area between the branchiostegal rays. Crepidostomum sp., Proteocephalus sp., Raphidascaris acus (formerly Contracaecum sp.), and Rhabdochona cotti infected the intestine. Diplostomum sp. (formerly Diplostomum spathaceum) was found in the eye orbit, gonads, kidney, liver, and mesenteries. Neascus sp. infected the integument and Posthodiplostomum sp. occurred in the mesenteries. Tetracotyle sp. was found in the gonads, kidney, liver, mesenteries, muscle, and on the surface of the urinary bladder.

Gyrodactylus bairdi, Crepidostomum sp., and R. cotti were the only helminths found that mature in sculpins

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(Hoffman, 1967). The other trematode species occurred as larvae called metacercariae. Gyrodactylus bairdi, Crepidostomum sp., Neascus sp., Posthodiplostomum sp., Proteocephalus sp., R. acus and Trichodina sp. had low prevalences and/or low mean intensities. Epistylis sp. had the highest prevalence of the external parasites found on sculpins. There were no significant difference in the prevalence of Epistylis sp. or Myxobolus sp. between seasons.

The number of parasite species found and the number of species whose individuals were counted increased from FCU (7/4) to FEX (8/5) to FCD (11/7). The helminth fauna of sculpins from each site, made up of those species whose individuals were counted, are primarily composed of Tetracotyle metacercariae, followed by Diplostomum metacercariae and then R. cotti, demonstrating that the helminth faunas are similar between sites. The helminths that will be discussed further are: Diplostomum sp., Tetracotyle sp., and R. cotti.

Comparisons of the mean numbers of the common parasite species of sculpins between sites for the total sampling period show no significant differences for Diplostomum sp. and R. cotti. Sculpins collected from FEX had the highest mean number of Diplostomum sp., followed by sculpins at FCD. Sculpins from FCU and FEX had significantly higher mean numbers of Tetracotyle sp. than sculpins from FCD. Tetracotyle sp. and R. cotti decreased in numbers from the upriver to the downriver sites.

Greater infection levels of Tetracotyle sp. and R. cotti in sculpins from FCU in comparison to FEX and FCD likely result from the higher productivity with accompanying algal growth observed there. It is apparent that FCU has a greater nutrient load due to some organic enrichment from Channing, Michigan, and from non-point sources (cattle grazing and a mink farm). Also the bottom substrate differs between sites with boulders and gravel at FCU, gravel-sand at FEX, and mostly sand at FCD. A combination of this nutrient enrichment which increases productivity and boulder-gravel substrate at FCU presumably increases the number of snails and mayfly larvae that serve as intermediate hosts for Tetracotyle sp. and R. cotti, respectively, that tends to favor high infection levels in sculpins. The transitional decrease and lower infection levels observed at FEX and FCD are presumably due to the lessened effect of effluents and lack of substrate heterogeneity.

Another explanation for this transitional decrease in numbers of Tetracotyle sp. and R. cotti may be due to

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differences in the lengths of sculpins examined from each site.  Sculpins from FCU were significantly larger than sculpins from FEX and FCD but it appears this was not responsible for the trends shown by Diplostomum sp. and Tetracotyle sp.

Correlation coefficients between the length of infected sculpins and the number of their common parasites are in Table 10.4.  The number of R. cotti significantly increased as sculpins from FEX and FCD increased in length and can be explained by the fact that as sculpins become larger (older), they eat more mayfly larvae, which serve as intermediate hosts for R. cotti (Hoffman, 1967).  The number of Tetracotyle sp. decreased at FCU and FEX and the number of Diplostomum sp. decreased at all sites as sculpins increased in length and may be explained by a change in the sculpins' behavior and/or habitat.  Close or direct contact between sculpins and cercariae (infective stage of trematodes) is required for penetration of the fish by the cercariae.  Thus fish must be present where infected snails are or swim into the infected areas since cercariae have a limited swimming ability.  Based on our observations, as sculpins become older, they move from the shallows to the deeper water.  Slyczynska - Jurewuz (1959) utilized cages to show that fish have a greater tendency to become infected with Diplostomum as they move closer to shore.

The mean number comparisons of Diplostomum sp., Tetracotyle sp., and R. cotti in sculpins between seasons at each site are in Table 10.5.  The highest mean numbers of Diplostomum sp. in sculpins occurred in fall, 1983 at FEX and FCD and in spring 1984 at FEX.  The mean numbers of Tetracotyle sp. were highest in sculpins in fall 1983 at all sites and in fall 1984 at FEX.  Sculpins collected from FCU and FEX in spring and fall 1983 and from FEX in spring 1984 had high numbers of R. cotti.  An explanation for the "trends" in 1983 demonstrated by Diplostomum sp. and Tetracotyle sp. is that 1983 was almost a drought year and young of the year sculpins had high numbers of parasites as indicated by the correlation data.  Young of the year sculpins presumably were concentrated with the infected snail intermediate hosts of Diplostomum sp. and Tetracotyle sp., during low water thus an increase in the numbers of Dilostomum sp. and Tetracotyle sp. was seen through 1983. This sculpin cohort then "carried over" its large number of parasites into spring 1984 at FEX.

## Results and Discussion - Longnose Dace

The parasite faunas of longnose dace from the three sites are in Tables 10.6, 10.7, and 10.8. Eight hundred sixty-two (98%) of the 878 dace examined were infected with at least one parasite species. Eleven parasite species (1 Monogenea, 2 Digenea, 2 Cestoda, 3 Nematoda, 3 Protozoa) were recovered. The number of species found and the number of species whose individuals were counted, were similar between sites. Gyrodactylus sp., Epistylis sp., Myxobolus sp., and Trichodina sp. infected the gills. Ligula sp. occurred in the hemocoel while Neascus sp. infected the integument, muscle, and the area between the branchiostegal rays and fins. Posthodiplostomum m. minimum occurred in the gonads, kidney, liver, and mesenteries. Raphidascaris acus (formerly Contracaecum sp.), Haplonema hamulatum (formerly Haplonema sp.), Cystidicoloides tenuissima (formerly Metabronema salvelini), and Rhabdochona canadensis were found in the intestine. Of the helminths found, only Gyrodactylus sp. and R. canadensis obtain maturity on and in dace, respectively (Hoffman, 1967). Ligula sp. occurred as larvae (plerocercoids), while Neascus sp. and P. m. minimum occurred as metacercariae.

Gyrodactylus sp., Ligula sp., Proteocephalus sp., C. tenuissima, H. hamulatum, R. acus, and Myxobolus sp. were infrequent in their occurrence and/or had low mean intensities. Epistylis sp. had the highest prevalence of the external parasites found on dace at each site. There was no significant difference in the prevalence of Epistylis sp. between seasons.

The helminth fauna of dace from each site, made up of those species whose individuals were counted, are primarily composed of P. m. minimum, followed by Neascus sp., and then R. canadensis indicating that the helminth faunas are similar between sites. These results are similar to those of Fischthal (1953), who found that Neascus sp. and P. m. minimum were the most common parasites encountered in stream fishes.

Comparisons of the mean numbers of P. m. minimum and Neascus sp. between sites for the total sampling period show that dace from FCU had significantly higher mean numbers then dace from FEX and FCD. Dace infected with P. m. minimum from FCU and FEX had significantly larger mean total lengths than dace from FCD. Dace from FCU had a higher mean number of R. canadensis than dace from FEX and FCD; although the differences were not significant. There were no significant differences in the mean total lengths

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of dace infected with Neascus sp. and R. canadensis between sites. In general, both the prevalence and mean number of P. m. minimum, Neasucs sp., and R. canadensis decreased from the upriver to the downriver sites. Greater infection levels of these parasite species in dace from FCU to the downriver sites likely result from the higher productivity with accompanying algal growth observed there and the differences in bottom substrate. These factors presumably increase the numbers of intermediate hosts for these parasites which in turn increase the infection levels in dace at FCU. Vinikour (1977) reported that longnose dace infected with Neascus rhinichthysi from one river with greater nutrient loads had significantly greater infection levels than dace collected from another river with lower nutrient loads.

Correlation coefficients between the total length of infected dace and the number of P. m. minimum, Neascus sp., and R. canadensis are all significant and are in Table 10.9. The increase in the number of Neascus sp. and P. m. minimum metacercariae with an increase in dace length may depend on a longer exposure time to parasitism, since body length is generally determined by age, and/or changes in the behavior of dace. The increase in R. candensis in dace can be explained by the fact that as dace become larger (older), they eat more mayfly larvae, which serve as the intermediate hosts for R. canadensis (Hoffman, 1967).

The mean number comparisons of P. m. minimum, Neascus sp., and R. canadensis in dace between seasons at each site are in Table 10.10. Several significant differences exist for P. m. minimum and Neascus sp. and the mean total length of infected dace between seasons. However, trends in mean numbers that occurred in one year were not repeated in the next year (i.e. the mean number of Neascus sp. in dace at FCU and FCD increased from spring through winter 1983; this trend was not repeated in 1984 or 1985.

## Summary

The parasite faunas of mottled sculpins between sites were comparable taxonomically and in species numbers. This was also true for the parasite faunas of longnose dace between sites. The parasite faunas of each fish species at each site were composed primarily of larval parasites that mature in fish eating birds and fish. Only R. cotti and Crepidostomum sp., and R. canadensis mature in sculpin and dace, respectively. Quantitatively, P. m. minimum metacercariae and Tetracotyle metacercariae were the most common endohelminths of dace and sculpins, respectively.

*Epistylis* sp. was the most common external parasite of dace and sculpins at each site. Significant differences in the prevalence and mean number of the parasite species were not found between sexes of either host species. Seasonal trends in infection rates of the parasites were not observed or were not repeated from one year to the next. In dace, the number of P. m. minimum, Neascus sp., and R. canadensis at all sites, and the number of R. cotti in sculpins at FEX and FCD significantly increased as host length increased. The number of Diplostomum sp. decreased at all sites and the number of Tetracotyle sp. decreased at FCU as sculpins increased in length. Tetracotyle sp. and R. cotti in sculpins and P. m. minimum, Neascus sp., and R. canadensis in dace decreased in numbers from the upriver to the downriver sites.

## Future Research

Longnose dace and mottled sculpins will be collected seasonally from FCU, FEX, and FCD in 1986. The prevalence and mean number of the parasites infecting these fish species will be calculated. Statistical analyses for separating prevalences and mean numbers of the parasites found will be performed to determine differences between fish sex, sites, seasons, and years. Correlation analyses will be performed to demonstrate trends between fish length and the number of the common parasite species. Also, the role of abiotic environmental factors and their influence on parasite populations will be addressed and integrated into the objectives discussed above.

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Table 10.1. Parasite fauna of 108 mottled sculpins from FCU during May
1983 through November 1984.

| Parasite | No. infect. (%) | No. counted (% of comm.) | Mean number $\pm$ SD |
|---|---|---|---|
| **Trematoda** | | | |
| Gyrodactylus bairdi | 1 (1) | -- | -- |
| Diplostomum sp. | 58 (54) | 212 (7.1) | 3.7 $\pm$ 4.3 |
| Tetracotyle sp. | 105 (97) | 2690 (89.9) | 25.6 $\pm$ 25.1 |
| **Nematoda** | | | |
| Rhabdochona cotti | 40 (37) | 90 (3.0) | 2.3 $\pm$ 1.9 |
| **Protozoa** | | | |
| Epistylis sp. | 67 (62) | -- | -- |
| Myxobolus sp. | 10 (9) | -- | -- |

Table 10.2. Parasite fauna of 208 mottled sculpins from FEX during May 1983 through November 1984

| Parasite | No. infect. (%) | No. counted (% of comm.) | Mean number ± SD |
|---|---|---|---|
| **Trematoda** | | | |
| Gyrodactylus bairdi | 1 (0.5) | -- | -- |
| Crepidostomum sp. | 6 (3) | 70 (1.50) | 11.7 ± 8.4 |
| Diplostomum sp. | 93 (45) | 609 (13.28) | 6.6 ± 8.9 |
| Tetracotyle sp. | 205 (99) | 3727 (81.30) | 18.2 ± 12.7 |
| **Nematoda** | | | |
| Raphidascaris acus | 2 (1) | 2 (0.01) | 1.0 |
| Rhabdochona cotti | 90 (43) | 179 (3.91) | 1.9 ± 1.4 |
| **Protozoa** | | | |
| Epistylis sp. | 154 (74) | -- | -- |
| Myxobolus sp. | 54 (26) | -- | -- |

Table 10.3. Parasite fauna of 199 mottled sculpins from PCD during May 1983 through November 1984.

| Parasite | No. infect. (%) | No. counted (% of comm.) | Mean number ± SD |
|---|---|---|---|
| Trematoda | | | |
| Gyrodactylus bairdi | 1 (0.5) | -- | -- |
| Crepidostomum sp. | 5 (3) | 24 (0.89) | 4.8 ± 0.8 |
| Diplostomum sp. | 79 (40) | 350 (13.07) | 4.4 ± 5.6 |
| Neascus sp. | 2 (1) | 2 (0.01) | 1.0 |
| Posthodiplostomum sp. | 1 (0.5) | 1 (0.01) | 1.0 |
| Tetracotyle sp. | 185 (94) | 2254 (84.20) | 12.2 ± 14.8 |
| Cestoda | | | |
| Proteocephalus sp. | 4 (2) | | |
| Nematoda | | | |
| Rhabdochona cotti | 36 (18) | 46 (1.72) | 1.3 ± 1.2 |
| Protozoa | | | |
| Epistylis sp. | 143 (73) | | |
| Myxobolus sp. | 42 (21) | | |
| Trichodina sp. | 2 (1) | | |

Table 10.4. Correlation coefficients between length of infected mottled sculpins and number of _Diplostomum_ sp., _Tetracotyle_ sp., and _Rhabdochona cotti_ by site.

| Site | Diplostomum sp. | Tetracotyle sp. | Rhabdochona cotti |
|------|-----------------|-----------------|-------------------|
| FCU | -0.04, .382, 58+ | -0.20, .032, 105* | 0.43, .405, 40 |
| FEX | -0.02, .432, 93 | -0.09, .142, 205 | 0.28, .009, 90* |
| FCD | -0.21, .059, 79 | 0.16, .032, 185* | 0.35, .025, 36* |

+ Correlation coefficient, significance level, number of infected fish.

* Significant at the 0.05 level or more.

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Table 10.5 Mean number ± SD comparisons of _Diplostomum_ sp., _Tetracotyle_ sp., and _Rhabdochona_ _cotti_ in mottled sculpins between seasons within each year at each site.

| | | 1983 | | | 1984 | |
| --- | --- | --- | --- | --- | --- | --- |
| Site | Spring | Summer | Fall | Spring | Summer | Fall |
| _Diplostomum_ sp. | | | | | | |
| FCU | 1.0 | 5.1 ± 6.2 | 3.5 ± 2.9 [1] | -- | -- | 1.6 ± 0.9 |
| FEX | 3.5 ± 3.0 | 2.6 ± 3.1 | 6.4 ± 7.7 | 13.9 ± 13.6 | 3.6 ± 3.5 | 3.0 ± 2.6 |
| FCD | 1.0 | 2.8 ± 2.7 | 7.6 ± 8.3 | 2.8 ± 1.9 | 2.8 ± 1.8 | 2.6 ± 2.4 |
| _Tetracotyle_ sp. | | | | | | |
| FCU | 9.5 ± 7.9 | 22.9 ± 20.8 | 34.3 ± 28.9 | -- | -- | 22.0 ± 24.0 |
| FEX | 13.0 ± 6.8 | 13.2 ± 10.6 | 23.0 ± 15.6 | 18.9 ± 11.4 | 16.9 ± 12.9 | 21.2 ± 12.9 |
| FCD | 10.4 ± 6.4 | 7.8 ± 8.2 | 12.1 ± 9.1 | 8.8 ± 6.4 | 22.9 ± 35.2 | 11.9 ± 7.4 |
| _Rhabdochona_ _cotti_ | | | | | | |
| FCU | 3.7 ± 2.3 | 1.0 | 2.5 ± 2.1 | -- | -- | 1.3 ± 0.5 |
| FEX | 1.7 ± 0.9 | 1.3 ± 0.4 | 2.3 ± 1.7 | 2.8 ± 1.8 | 1.3 ± 0.5 | 1.2 ± 0.4 |
| FCD | 1.2 ± 0.4 | 1.3 ± 0.5 | 1.3 ± 0.5 | 1.3 ± 0.6 | 1.7 ± 1.2 | 1.0 |

[1] Entries underscored within the same year by the same line are not significantly different at the 0.05 level.

Table 10.6. Parasite fauna of 197 longnose dace from FCU during May 1983 through October 1985.

| Parasite | No. infect. (%) | No. counted (% of comm.) | Mean number ± SD |
|---|---|---|---|
| **Trematoda** | | | |
| Gyrodactylus sp. | 4 (2) | -- | -- |
| Neascus sp. | 168 (85.2) | 1223 (12.00) | 7.3 ± 10.5 |
| Posthodiplostomum p. minimum | 189 (95.9) | 8531 (83.90) | 45.1 ± 61.8 |
| **Cestoda** | | | |
| Ligula sp. | 7 (3.5) | 7 (0.10) | 1.0 |
| Proteocephalus sp. | 6 (3) | 7 (0.10) | 1.2 ± 0.4 |
| **Nematoda** | | | |
| Haplonema hamulatum | 16 (8.1) | 30 (0.29) | 1.9 ± 2.1 |
| Cystidicoloides tenuissima | 1 (0.5) | 1 (0.01) | 1.0 |
| Rhabdochona canadensis | 88 (44.7) | 366 (3.60) | 4.2 ± 7.1 |
| **Protozoa** | | | |
| Epistylis sp. | 55 (27.9) | -- | -- |
| Myxobolus sp. | 4 (2) | -- | -- |
| Trichodina sp. | 34 (17.3) | -- | -- |

Table 10.5 Mean number $\pm$ SD comparisons of <u>Diplostomum</u> sp., <u>Tetracotyle</u> sp., and <u>Rhabdochona</u> <u>cotti</u> in mottled sculpins between seasons within each year at each site.

| | 1983 | | | 1984 | | |
|------|------|------|------|------|------|------|
| Site | Spring | Summer | Fall | Spring | Summer | Fall |

<u>Diplostomum</u> sp.

| | | | | | | |
|------|------|------|------|------|------|------|
| FCU | 1.0 | 5.1 $\pm$ 6.2 | 3.5 $\pm$ 2.9 | -- | -- | 1.6 $\pm$ 0.9 |
| FEX | 3.5 $\pm$ 3.0 | 2.6 $\pm$ 3.1 | 6.4 $\pm$ 7.7 | 13.9 $\pm$ 13.6 | 3.6 $\pm$ 3.5 | 3.0 $\pm$ 2.6 |
| FCD | 1.0 | 2.8 $\pm$ 2.7 | 7.6 $\pm$ 8.3 | 2.8 $\pm$ 1.9 | 2.8 $\pm$ 1.8 | 2.6 $\pm$ 2.4 |

<u>Tetracotyle</u> sp.

| | | | | | | |
|------|------|------|------|------|------|------|
| FCU | 9.5 $\pm$ 7.9 | 22.9 $\pm$ 20.8 | 34.3 $\pm$ 28.9 | -- | -- | 22.0 $\pm$ 24.0 |
| FEX | 13.0 $\pm$ 6.8 | 13.2 $\pm$ 10.6 | 23.0 $\pm$ 15.6 | 18.9 $\pm$ 11.4 | 16.9 $\pm$ 12.9 | 21.2 $\pm$ 12.9 |
| FCD | 10.4 $\pm$ 6.4 | 7.8 $\pm$ 8.2 | 12.1 $\pm$ 9.1 | 8.8 $\pm$ 6.4 | 22.9 $\pm$ 35.2 | 11.9 $\pm$ 7.4 |

<u>Rhabdochona</u> <u>cotti</u>

| | | | | | | |
|------|------|------|------|------|------|------|
| FCU | 3.7 $\pm$ 2.3 | 1.0 | 2.5 $\pm$ 2.1 | -- | -- | 1.3 $\pm$ 0.5 |
| FEX | 1.7 $\pm$ 0.9 | 1.3 $\pm$ 0.4 | 2.3 $\pm$ 1.7 | 2.8 $\pm$ 1.8 | 1.3 $\pm$ 0.5 | 1.2 $\pm$ 0.4 |
| FCD | 1.2 $\pm$ 0.4 | 1.3 $\pm$ 0.5 | 1.3 $\pm$ 0.5 | 1.3 $\pm$ 0.6 | 1.7 $\pm$ 1.2 | 1.0 |

[1] Entries underscored within the same year by the same line are not significantly different at the 0.05 level.

Table 10.6.  Parasite fauna of 197 longnose dace from FCU during May 1983 through October 1985.

| Parasite | No. infect. (%) | No. counted (% of comm.) | Mean number ± SD |
|---|---|---|---|
| **Trematoda** | | | |
| Gyrodactylus sp. | 4 (2) | -- | -- |
| Neascus sp. | 168 (85.2) | 1223 (12.00) | 7.3 ± 10.5 |
| Posthodiplostomum m. minimum | 189 (95.9) | 8531 (83.90) | 45.1 ± 61.8 |
| **Cestoda** | | | |
| Ligula sp. | 7 (3.5) | 7 (0.10) | 1.0 |
| Proteocephalus sp. | 6 (3) | 7 (0.10) | 1.2 ± 0.4 |
| **Nematoda** | | | |
| Haplonema hamulatum | 16 (8.1) | 30 (0.29) | 1.9 ± 2.1 |
| Cystidicoloides tenuissima | 1 (0.5) | 1 (0.01) | 1.0 |
| Rhabdochona canadensis | 88 (44.7) | 366 (3.60) | 4.2 ± 7.1 |
| **Protozoa** | | | |
| Epistylis sp. | 55 (27.9) | -- | -- |
| Myxobolus sp. | 4 (2) | -- | -- |
| Trichodina sp. | 34 (17.3) | -- | -- |

Table 10.7. Parasite fauna of 340 longnose dace from FEX during May 1983 through October 1985.

| Parasite | No. infect. (%) | No. counted (% of comm.) | Mean number ± SD |
|---|---|---|---|
| **Trematoda** | | | |
| Gyrodactylus sp. | 14 (4.1) | -- | -- |
| Neascus sp. | 238 (70) | 890 (7.80) | 3.7 ± 3.4 |
| Posthodiplostomum m. minimum | 299 (87.9) | 10079 (88.80) | 33.7 ± 44.2 |
| **Cestoda** | | | |
| Ligula sp. | 23 (6.8) | 33 (0.30) | 1.4 ± 1.1 |
| Proteocephalus sp. | 9 (2.6) | 20 (0.20) | 2.2 ± 2.4 |
| **Nematoda** | | | |
| Haplonema hamulatum | 39 (11.4) | 96 (0.80) | 2.5 ± 2.4 |
| Raphidascaris acus | 1 (0.3) | 2 (0.01) | 2.0 |
| Rhabdochona canadensis | 94 (27.6) | 224 (2.00) | 2.4 ± 2.5 |
| **Protozoa** | | | |
| Epistylis sp. | 129 (37.9) | -- | -- |
| Myxobolus sp. | 18 (5.3) | -- | -- |
| Trichodina sp. | 59 (17.3) | -- | -- |

Table 10.8. Parasite fauna of 341 longnose dace from PCD during May 1983 through October 1985.

| Parasite | No. infect. (%) | No. counted (% of comm.) | Mean number ± SD |
|---|---|---|---|
| **Trematoda** | | | |
| Gyrodactylus sp. | 12 (3.5) | -- | -- |
| Neascus sp. | 199 (58.3) | 779 (13.30) | 3.9 ± 6.8 |
| Posthodiplostomum | | | |
| m. minimum | 261 (76.5) | 4713 (80.80) | 18.0 ± 35.1 |
| **Cestoda** | | | |
| Ligula sp. | 12 (3.5) | 15 (0.30) | 1.3 ± 0.5 |
| Proteocephalus sp. | 22 (6.5) | 54 (0.90) | 2.4 ± 3.3 |
| **Nematoda** | | | |
| Haplonema hamulatum | 31 (9.1) | 100 (1.70) | 3.2 ± 3.9 |
| Rhabdochona canadensis | 53 (15.5) | 175 (3.00) | 3.3 ± 3.5 |
| **Protozoa** | | | |
| Epistylis sp. | 179 (52.4) | -- | -- |
| Myxobolus sp. | 9 (2.6) | -- | -- |
| Trichodina sp. | 76 (22.2) | -- | -- |

Table 10.9. Correlation coefficients between the length of infected longnose dace and number of _Posthodiplostomum_ _m_. _minimum_, _Neascus_ sp., and _Rhabdochona_ _canadensis_ by site.

| Site | _Posthodiplostomum_ _m_. _minimum_ | _Neascus_ sp. | _Rhabdochona_ _canadensis_ |
|------|------------------------------------|---------------|----------------------------|
| FCU | 0.67, .001, 189[+]* | 0.35, .001, 168* | 0.33, .001, 88* |
| FEX | 0.58, .001, 299* | 0.35, .001, 238* | 0.24, .010, 94* |
| FCD | 0.45, .001, 261* | 0.26, .001, 199* | 0.73, .001, 53* |

[+] Correlation coefficient, significance level, number of infected fish.

* Significant at the 0.05 level or more.

Table 10.10. Mean number ± SD comparisons of *Posthodiplostomum* p. *minimum*, *Rhabdo* sp. and *Rhabdochona canadensis* in longnose dace between seasons within each year at each site.

| Site | 1983 | | | | 1984 | | | | 1985 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Spring | Summer | Fall | Winter | Spring | Summer | Fall | Winter | Spring | Summer | Fall |
| **Posthodiplostomum p. minimum** | | | | | | | | | | | |
| PCB | 20.0 ± 22.3 | 80.4 ± 96.8 | 77.0 ± 77.3 | 61.8 ± 70.8 | -- | -- | 17.8 ± 18.3 | -- | 83.2 ± 43.7 | 36.7 ± 47.4 | 38.8 ± 10.1 |
| PEB | 13.0 ± 22.7 | 31.2 ± 41.8 | 38.8 ± 34.4 | 44.3 ± 34.3 | 66.0 ± 43.8 | 38.6 ± 73.3 | 29.3 ± 43.8 | 37.4 ± 30.6 | 13.4 ± 34.0 | 36.7 ± 38.8 | 32.8 ± 28.0 |
| PCD | 1.8 ± 0.8 | 0.3 ± 0.8 | 13.3 ± 13.7 | 28.1 ± 31.7 | 20.3 ± 13.0 | 40.4 ± 80.0 | 2.7 ± 1.8 | 3.8 ± 8.8 | 22.8 ± 39.2 | 13.8 ± 12.8 | 8.0 ± 12.8 |
| **Rhabdo sp.** | | | | | | | | | | | |
| PCB | 2.3 ± 3.7 | 0.3 ± 0.8 | 0.8 ± 0.7 | 3.8 ± 7.0 | -- | -- | 0.8 ± 8.0 | -- | 13.4 ± 18.0 | 13.0 ± 13.0 | 0.8 ± 12.3 |
| PEB | 2.0 ± 2.3 | 2.8 ± 1.0 | 2.8 ± 1.8 | 3.8 ± 3.4 | 4.1 ± 3.0 | 3.0 ± 4.0 | 2.7 ± 2.7 | 2.0 ± 3.0 | 3.4 ± 3.8 | 2.0 ± 2.3 | 4.0 ± 3.8 |
| PCD | 1.2 ± 0.4 | 2.7 ± 2.0 | 2.0 ± 2.8 | 4.3 ± 4.8 | 4.1 ± 0.1 | 8.8 ± 13.0 | 1.8 ± 0.8 | 1.0 ± 0.0 | 3.0 ± 2.1 | 3.1 ± 1.3 | 3.0 ± 1.8 |
| **Rhabdochona canadensis** | | | | | | | | | | | |
| PCB | 2.1 ± 1.0 | 3.3 ± 1.0 | 0.8 ± 8.0 | 3.0 ± 1.0 | -- | -- | 1.8 ± 1.0 | -- | 8.0 ± 13.0 | 1.0 ± 0.8 | 2.7 ± 2.3 |
| PEB | 3.0 ± 3.8 | 1.0 ± 1.1 | 3.0 ± 2.0 | 2.2 ± 8.0 | 3.1 ± 2.3 | 2.3 ± 1.8 | 1.0 ± 1.1 | 1.3 ± 0.7 | 3.4 ± 3.7 | 2.0 ± 1.3 | 3.3 ± 2.3 |
| PCD | 1.8 ± 0.8 | 4.1 ± 4.8 | 1.3 ± 0.8 | 1.8 ± 0.8 | 1.3 ± 0.4 | 0.8 ± 4.7 | 1.0 ± 0.0 | 3.8 ± 3.1 | 2.7 ± 1.8 | 3.3 ± 1.3 | 3.8 ± 1.0 |

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SUBCONTRACT NUMBER: E 06549-84-C-008


ELF COMMUNICATIONS SYSTEM ECOLOGICAL MONITORING PROGRAM:
WETLAND STUDIES


ANNUAL REPORT 1985

ELF COMMUNICATIONS SYSTEM ECOLOGICAL MONITORING PROGRAM:

WETLAND STUDIES

ANNUAL REPORT, 1985

SUBCONTRACT NUMBER: E06549-84-C-008

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# ABSTRACT

This report summarizes continuing work examining potential effects of ELF generated electromagnetic fields on peatland systems in northern Wisconsin. Statistical analyses of decomposition data for 1984 and 1985 demonstrated no significant relationships between weight loss and either environmental or ELF variables. Nested ANOVA, linear regression and stepwise linear regression of foliar nutrients resulted in some significant correlations and interactions although the factors involved explained little of the variance in the data. Investigation of nitrogen fixation rates was shifted from use of Alder/Frankia systems to examination of microbial activity associated with Sphagnum and peat. Boardwalks were installed in critical areas to protect site integrity.

SUMMARY

This report summarizes the results of field studies and
laboratory analyses from 1984 and 1985, in which we have been
investigating the possible effects of ELF electromagnetic fields
on peatlands in the vicinity of the Wisconsin Test Facility.  Our
studies are concerned with foliar nutrient concentrations, rates
of decomposition, stomatal function, and nitrogen fixation that
could be influenced by ELF electromagnetic fields.

Eleven bog sites were sampled approximately monthly, using
the sampling plan developed during 1984.  This permitted direct
association of experimental parameters with environmental data.
Boardwalks were installed in sensitive areas to prevent
deterioration of the sample plots.

Foliar samples, were collected in June, July, and September,
1984. Sample size was increased from 20 to 30 replicates per bog.
Analysis of sample sets for spruce and leatherleaf indicate
seasonal changes. For example, in leatherleaf, potassium declined
from June to September, while calcium and magnesium increased.
Using a multiple linear regression model, nutrient concentrations
were examined with respect to environmental factors and ELF field
variables.  Nested analysis of variance and discriminant analysis
models were used in an attempt to distinguish the categories of
bogs along the ELF field gradient.  In a few cases, statistically
significant relationships were found, but the level of
significance was low; tests using linear regression analysis
indicated that although there were significant correlations, the

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variables generally accounted for only 6 to 12 percent of the
variance in foliar nutrient content. When relationships were
further tested using stepwise regression analysis, the parameters
generally selected accounted for a relatively small part of the
variance with one exception. Nine variables, including ELF air
and magnetic fields, accounted for 90% of the variance of black
spruce potassium foliar concentrations. Plots of these variables
indicate that this pattern is ambiguous. Additional data from
1985 did not exhibit the same pattern.

Discriminant analysis was utilized to examine the combined
relationships of calcium, potassium, and magnesium in separating
the sites for a given plant species. Again, potassium content
appeared to be a factor separating bogs.

Several sets of detailed trials were initiated to determine
the appropriate protocol for measuring the amount of stomatal
resistance relative to environmental and ELF variables.
Leatherleaf was chosen for further work after testing three
species. Initial studies indicated variability in the same range
as that found for leaf nutrient concentrations, i.e. about 20%.

Nitrogen fixation is another process important to growth of
bog plants and thus to community and ecosystem function. We had
originally planned to used speckled alder, but work with that
species proved unacceptable because cuttings were difficult to
root. In 1985, we began work on microorganisms associated with
the sphagnum moss and peat. The initial tests revealed some
procedural problems that will be addressed in sampling during the
coming field season.

Four sets of decomposition samples were analysed (two from
1984 and two from 1985); one of these involved the use of
Labrador Tea leaves, a natural bog material. In general,
variation in weight loss proved lower with Labrador Tea than with
the cellulose squares. Correlation between decomposition rate
and environmental factors and ELF variables appeared weak.

Sampling will continue during the 1986 field season, when it
is anticipated that the ELF antenna will be functioning
continuously.

## INTRODUCTION

The objective of this research is to determine whether long-term exposure to ELF electromagnetic fields can significantly influence the stability and functioning of peatland ecosystems. A series of experiments with plants exposed to high intensity 60Hz fields ( >200v/M) suggest that if ELF fields were to have any effect, that the site of action of the applied fields would be the cell membrane (Inoue et al. 1985, Miller et al. 1980,1983). Therefore, we chose a set of parameters important to peatland structure and function which could be potentially affected at the membrane level. The four parameters chosen for investigation were: decomposition, foliar nutrient content, nitrogen fixation, and stomatal resistance. Alterations in these processes could have potentially important effects at the system level.

A series of eleven peatland sites located along the electromagnetic field gradient produced by the Wisconsin Test Facility were chosen for study (Appendix D). These eleven sites have similar species composition, structure, and environmental characteristics. All sites have an organic peat (histosol) substrate formed by the partial decomposition of mosses and vascular plants.

In 1984, each site was visited monthly (May-October) and samples collected according to our experimental design and sampling protocol. Sampling protocols for both foliar nutrient content and the decomposition studies were modified after examining the results of 1983 preliminary studies and will be

discussed in detail later. In 1984 and 1985, preliminary studies
of nitrogen fixation and leaf transpiration were performed to
determine suitable methodology and the potential of these
measurements for field study within our experimental design.

# EXPERIMENTAL DESIGN

This study was designed to employ linear regression and analysis of variance techniques to identify any significant effects of ELF electromagnetic fields on measures of ecosystem function. Since the Wisconsin Test Facility has been operating for several years, we could not use a design that involves test vs. control paired plots. Instead, we are using a gradient analysis approach, with sites at selected positions along the 76 Hz (ELF) gradient (Appendix D). Each sampling date was considered independently and statistical analyses for the dependent variables performed separately.

Four categories of sites were selected, based on ELF intensity. The ANTENNA group includes wetlands adjacent to the antenna system, the INTERMEDIATE group are sites located between the antenna arms, the BACKGROUND group are sites that have field 76 Hz intensities at least two orders of magnitude lower than the antenna sites, and the GROUND sites are adjacent to the north ground terminal. We monitored three bogs in each of the ANTENNA, INTERMEDIATE, and BACKGROUND categories, and two GROUND transects within one large peatland (Table 1). The bogs are similar in vegetation composition and structure and in groundwater chemical constituents (see Stearns et al. 1984).

Within each site, a transect was established parallel to the nearest antenna arm or ground terminal. Six shallow groundwater wells were placed 10 m apart, and the environmental and experimental samples were collected from and adjacent to these well sites (Figure 1). In 1984 and 1985, plank boardwalks were
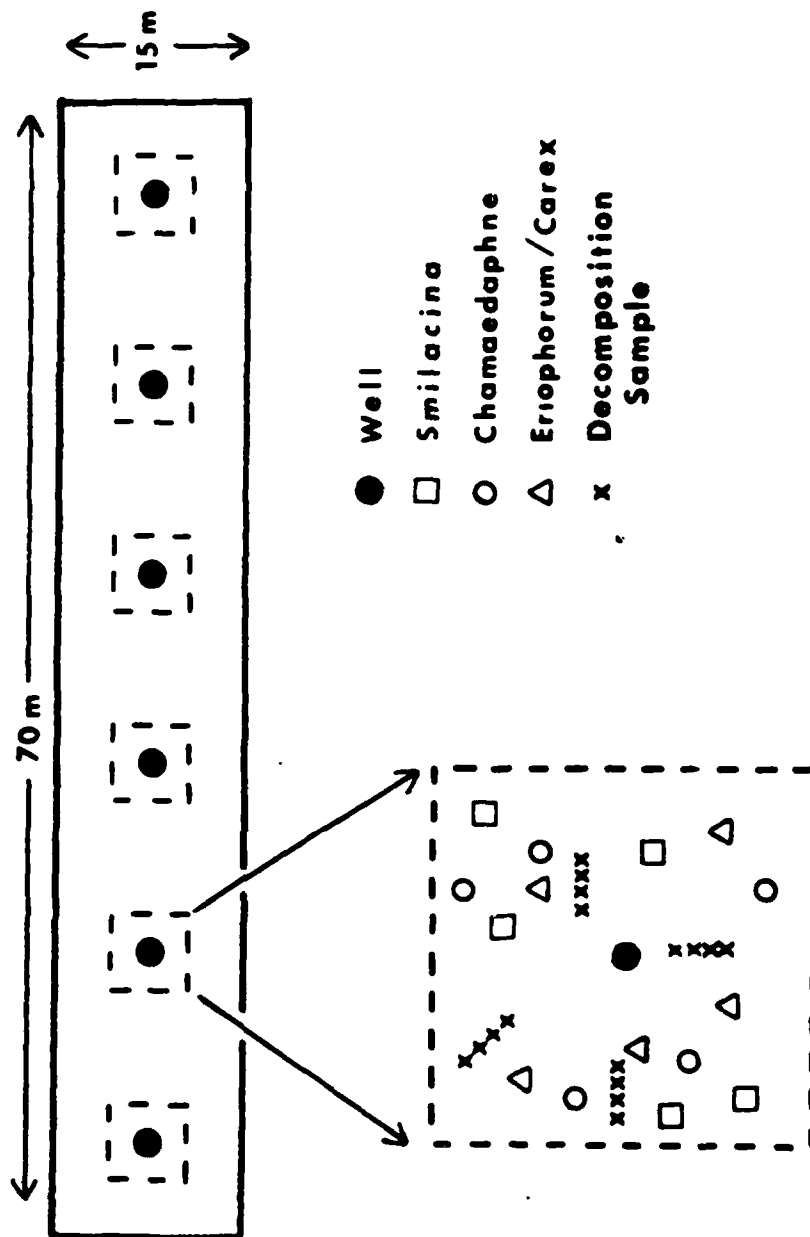
Figure 1. The 70 m X 15 m sampling plot used in 1984 and 1985 in each of the eleven study sites. Each plot was subdivided into six subplots. All of the foliar samples collected for nutrient analysis and the decomposition samples for each bog were partitioned among the six subplots. Interstitial bog water for chemical and physical analysis was collected from a well in each subplot.

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Table 1. A list of bogs investigated in 1984 and 1985.
See 1984 annual report for locations within the
Chequamegon National Forest.

| Bog Name | ELF Category |
|---|---|
| 101 | GROUND |
| 102 | GROUND |
| 21 | ANTENNA |
| 22 | ANTENNA |
| 40 | ANTENNA |
| 2 | INTERMEDIATE |
| 7 | INTERMEDIATE |
| 11 | INTERMEDIATE |
| 20 | BACKGROUND |
| 41 | BACKGROUND |
| 50 | BACKGROUND |

established along the trails leading to the transects wherever footing was uncertain. In 1985, planks were placed near each well to protect the adjacent bog mat. These measures proved successful in preventing major damage to the sites without altering surface water flow patterns.

## Analyses

All analyses were performed on a Sperry 1100 computer using procedures available in SPSS (Hull and Nie 1981). Sokal and Rohlf (1981) served as the principal statistical reference. Whenever our test data were proportions (between 0 and 1.0), we used a squareroot arcsin transformation to normalize that data set .

A nested analysis of variance model (shown below) was used to discern separation of categories of bogs, based on test data.

$Y_{ijk} = u + a_i + B_{ij} + e_{ijk}$, where:

$Y$ = sample value for an experimental parameter (dependent variable)

$u$ = grand mean

$a_i$ = ELF category     (ANTENNA, INTERMEDIATE, BACKGROUND, GROUND)

$B_{ij}$ = replicate bog nested within ELF category

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$e_{ijk}$ = error term

To test for subgroup (bog replicate) and group (ELF category) differences, we used the F statistic:

$$F = MS \text{ groups } / MS \text{ subgroups}$$

This tests the hypothesis that there is no difference among main groups (ELF categories).

Although we chose bogs that were structurally and chemically similar, there was some variation in bog structure and environmental chemistry. The nested design was used to separate variation inherent among the replicate bogs from variation assignable to the ELF category.

The nested ANOVA design used requires that all factors be balanced (i.e. equal samples / bog / category). Since we investigated 3 ANTENNA, 3 INTERMEDIATE, 3 BACKGROUND, and 2 GROUND sites (an unbalanced design), we performed analyses on all combinations of 2 bogs / category and on a design eliminating the GROUND sites (3 bogs / category) to balance our design. This also enabled us to more thoroughly understand the data, when one replicate bog or another influenced the results. All replicate samples from each well site from each bog were used.

Linear regression was used to determine direct correlation between experimental data and ELF fields (including air and earth electric fields and magnetic fields) and the environmental data.

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Simple correlation coefficients were determined from the following formula:

$$r = \sum xy \; / \; \text{SQRT}\left(\sum x^2 \; \sum y^2\right)$$

For those combinations that had relatively high correlation (P<.05), plots were drawn and appropriate regression equations developed.

Step-wise regression could then be performed between test results and the simplified list of environmental and ELF parameters, to see if combinations of parameters better explained the variance of the test data. The appropriate model used is:

Y = a + b1x1 + b2x2 + b3x3 + .....+ bnxn + e, where

Y = test parameter estimate (dependent variable)

x = ELF field or environmental parameter (independent variable)

b = partial regression coefficient

a = intercept when x1 = x2 = xn = 0

e = error term

Partial correlation coefficients (r) were determined for each independent .variable; in forward stepwise regression, those variables with the highest value of r were added first, then the

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second highest, and so on. We examined the multiple correlation coefficient ($R^2$), adjusted for degrees of freedom, and F = MS regression on xl-xn / MS error to determine the significance of the results. There was only one set of measurements taken at each well site each month for the environmental parameters and each year for the ELF field parameters as opposed to replicate samples for each of our test variables. In our correlation analyses we used the mean value associated with each well for each test variable with the environmental and ELF variables.

ENVIRONMENTAL PARAMETERS in 1984, 1985

A variety of environmental parameters were measured along each transect in each bog to assist in explaining test results (see Table 2 and 3). In 1984, measurements were made monthly in June, July, August, September, and October, while in 1985, measurements were made, monthly, May through September (APPENDIX A and B). We routinely measured pH, specific conductance (adjusted to 25 C), depth from peat surface to ground water, and water temperature, in the wells in the field.

Water samples were collected, filtered, and refrigerated for measurements of organic matter. Duplicate filtered water samples were acidified with $HNO_3$ for cation analysis. Organic matter and cation measurements were made later in the laboratory. Organic matter was measured in two different ways: by absorbance at 320 nm (color) (Gorham pers. comm.) and by direct combustion.

In 1984, we attempted measurements of the reducing ability of water in the root zone of the peat, by measuring Eh directly with a platinum electrode and by looking for AgS deposits on silver-plated rods inserted in the peat. Redox conditions may affect root function and the eventual nutrient status of plants so we felt it was important to determine potential differences between sites (Armstrong 1982). However, neither technique produced satisfactory results. In addition, we also measured depth to the water table as an index of redox conditions. This is not as precise a measure but depth of the water table and Eh can both be related to the aeration status of the root zone. In 1985, heavy precipitation throughout the summer caused high groundwater

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Table 2. Listing of environmental and ELF parameters collected in 1984. Environmental samples are all concentrations of ions and other properties of water in shallow wells in the bogs. * indicates the independent parameters used in analyses.

| FILE NAME | | PARAMETER | FILE NAME | | PARAMETER |
|---|---|---|---|---|---|
| JUNT | | June temperature | SEPZ | * | September water depth |
| JUNPH | * | June pH | SEPT | * | September temperature |
| JUNSPC | * | June spec. conductance | SEPPH | * | Sept. pH |
| JUNCA | | June Calcium | SEPSPC | * | Sept. spec. conductance |
| JUNMG | | June magnesium | SEPEH | * | Sept. Eh |
| JUNK | * | June potassium | SEPCA | | Sept. calcium |
| JUNAB | | June color (absorb.) | SEPMG | | Sept. magnesium |
| JUNOM | * | June organic carbon | SEPAB | | Sept. color (absorb.) |
| JULZ | * | July water depth | SEPOM | * | Sept. organic carbon |
| JULT | * | July temperature | SEPSI | | Sept. AgS depth |
| JULPH | * | July pH | OCTZ | | October water depth |
| JULSPC | * | July spec. conductace | OCTT | * | Oct. temperature |
| JULEH | * | July Eh | OCTPH | * | Oct. pH |
| JULCA | * | July calcium | OCTSPC | | Oct. spec. conductance |
| JULMG | * | July magnesium | OCTEH | * | Oct. Eh |
| JULK | * | July potassium | OCTCA | | Oct. calcium |
| JULAB | * | July color (absorb.) | OCTMG | | Oct. magnesium |
| JULOM | * | July organic carbon | OCTAB | * | Oct. color (absorb.) |
| AGZ | * | August water depth | OCTOM | | Oct. organic carbon |
| AGT | * | Aug. temperature | OCTSI | * | Oct. AgS depth |
| AGPH | * | Aug. pH | AIR | * | Electric field, air |
| AGSPC | * | Aug. spec. conductance | LOGAIR | * | Log 10 air field |
| AGEH | * | Aug. Eh | EARTH | * | Electric field, earth |
| AGCA | | Aug. calcium | MAG | * | Magnetic field |
| AGMG | | Aug. magnesium | LOGMAG | * | Log 10 magnetic field |
| AGK | * | Aug potassium | LOGEARTH | * | Log 10 earth field |
| AGAB | * | Aug. color (absorb.) | | | |
| AGOM | | Aug. organic carbon | | | |

Table 3.    Environmental and ELF parameters examined in 1985.
            Environmental variables were collected in
            groundwater wells in the bogs; many were analysed
            in the laboratory.

FILE NAME       PARAMETER

MAYT            May temperature
MAYPH           May pH
MAYSPC          May specific conductance
MAYCA           May calcium
MAYMG           May magnesium
MAYK            May potassium
MAYAB           May color (absorbance)
MAYZ            May water table depth
JUNT            June temperature
JUNSPC          June specific conductance
JUNCA           June calcium
JUNMG           June magnesium
JUNK            June potassium
JUNAB           June color (absorbance)
JUNZ            June water table depth
JULT            July temperature
JULPH           July pH
JULSPC          July specific conductance
JULCA           July calcium
JULMG           July magnesium
JULK            July potassium
JULAB           July color (absorbance)
AUGZ            August water table depth
AUGT            August temperature
AUGPH           August pH
AUGSPC          August specific conductance
AUGCA           August calcium
AUGMG           August magnesium
AUGK            August potassium
AUGAB           August color (absorbance)
SEPZ            September water table depth
SEPT            September temperature
SEPPH           September pH
SEPSPC          September specific conductance
SEPCA           September calcium
SEPMG           September magnesium
SEPK            September potassium
SEPAB           September color (absorbance)
EARTH           Electric field in earth
MAG             Magnetic field

in most sites, and we felt it was not important to use either the platinum electrode or the silver-plated rods since there was consistent water saturated surface peat. We did however, continue to measure water table depth in our wells.

A correlation matrix was developed to examine any collinearity between the environmental and ELF parameters. Any parameters that were highly correlated (r>.80) were reduced to a list of independent variables; these, in turn, could be used in regression analyses to better understand the variance in the test data ( see Table 2).

Calcium, potassium, and magnesium, are three important macronutrients in plant tissue whose concentration may be affected by ELF fields. These mineral nutrients play important roles in a plants' physiology and are active constituents of a number of important biochemical reactions.

We collected foliar samples several times during the growing season because the translocation of nutrients may vary seasonally and the pattern of nutrient accumulation may be affected. Chamaedaphne calyculata (Leatherleaf), Eriophorum spissum (cottongrass), and Carex oligosperma were collected three times: in June, July, and September. This represents early, middle, and late season periods of physiological activity. Smilacina trifolia was sampled only in June and July because leaves had senesced by the September sampling date. Picea mariana (black spruce) samples were collected only once in September. We found that the spruce trees selected for sampling were too small to tolerate monthly sampling. Therefore, we followed the recommendations of Swan (1970), who suggested that fall samples are the best to evaluate the nutrient status of black spruce.

We also increased the sample size for each species from 20 to 30 replicates in each bog to improve the precision of our statistical analyses. For most species five samples were collected in each of the six subplots in each bog (Fig 2). Because of their size and distribution, spruce samples were not

collected on a subplot basis. Instead thirty individuals were chosen randomly in each bog along a transect line that paralleled our subplots.

All foliar samples were prepared for analysis by digestion of 0.25 gram subsamples in a mixture of sulfuric acid and hydrogen peroxide that oxidizes the organic material in the sample (van Lietrop 1976). This technique was validated using National Bureau of Standards plant samples and spiked samples. The analyses of NBS standards were similiar to certified values (Appendix C) and spikes added to samples were satisfactorly recovered. NBS pine needle and citrus leaf standards are continually processed with our samples and analyzed as.a check on our laboratory procedures.

Complete sample sets for spruce and for leatherleaf have been analyzed for all three nutrient elements. The analysis of false solomon seal (Smilacina trifolia) and cottongrass (Eriophorum spissum) samples has been completed but are not presented in this report. We encountered a number of technical problems in atomic absorption analysis for calcium and potassium (which have been solved) that have delayed these results.

Mean concentrations (percent of dry weight) of potassium, calcium, and magnesium for leatherleaf and spruce foliar tissue are shown in tables 4 through 7. In leatherleaf, potassium generally declined between June and September while calcium and magnesium concentrations increased.

Table 4.    Cations in Leatherleaf leaves in June, 1984
            (% dry wt., Mean ±1 S.E.) N=Sample size

| Bog # | K | Ca | Mg | N |
|---|---|---|---|---|
| 101 | 0.680 (.019) | 0.401 (.023) | 0.097 (.003) | 29 |
| 102 | 0.736 (.019) | 0.295 (.012) | 0.095 (.002) | 30 |
| 21 | 0.814 (.017) | 0.297 (.010) | 0.105 (.003) | 30 |
| 22 | 0.755 (.015) | 0.325 (.012) | 0.098 (.001) | 30 |
| 40 | 0.641 (.021) | 0.306 (.017) | 0.089 (.003) | 30 |
| 2 | 0.597 (.015) | 0.402 (.016) | 0.114 (.003) | 30 |
| 7 | 0.720 (.019) | 0.333 (.016) | 0.102 (.003) | 30 |
| 11 | 0.661 (.018) | 0.378 (.014) | 0.099 (.003) | 30 |
| 20 | 0.744 (.020) | 0.397 (.012) | 0.105 (.002) | 30 |
| 41 | 0.786 (.024) | 0.356 (.011) | 0.114 (.002) | 30 |
| 50 | 0.720 (.014) | 0.276 (.009) | 0.100 (.002) | 30 |

Table 5.    Cations in Leatherleaf leaves for July, 1984
            (% dry wt., Mean +1 S.E.) N=Sample size

| Bog # | K | Ca | Mg | N |
|-------|-------------|-------------|-------------|----|
| 101 | 0.541 (.021) | 0.494 (.023) | 0.119 (.003) | 30 |
| 102 | 0.570 (.026) | 0.378 (.012) | 0.113 (.002) | 30 |
| 21 | 0.504 (.012) | 0.458 (.014) | 0.112 (.002) | 30 |
| 22 | 0.496 (.011) | 0.419 (.014) | 0.102 (.003) | 30 |
| 40 | 0.457 (.013) | 0.420 (.016) | 0.103 (.005) | 30 |
| 2 | 0.458 (.014) | 0.461 (.016) | 0.114 (.003) | 30 |
| 7 | 0.548 (.018) | 0.423 (.017) | 0.111 (.003) | 30 |
| 11 | 0.507 (.016) | 0.488 (.020) | 0.101 (.003) | 30 |
| 20 | 0.532 (.016) | 0.492 (.014) | 0.114 (.003) | 30 |
| 41 | 0.518 (.013) | 0.510 (.019) | 0.122 (.003) | 30 |
| 50 | 0.500 (.010) | 0.459 (.013) | 0.115 (.003) | 30 |

Table 6.    Cations in Leatherleaf leaves for September, 1984
            (% dry wt Mean $\pm 1$ S.E.) N=Sample size

| Bog # | K | Ca | Mg | N |
|-------|-----------|-----------|-----------|----|
| 101 | 0.495 (.012) | 0.706 (.040) | 0.135 (.004) | 30 |
| 102 | 0.535 (.015) | 0.631 (.031) | 0.129 (.005) | 30 |
| 21 | 0.533 (.014) | 0.689 (.026) | 0.137 (.004) | 30 |
| 22 | 0.530 (.014) | 0.655 (.027) | 0.119 (.003) | 30 |
| 40 | 0.487 (.014) | 0.605 (.023) | 0.117 (.004) | 30 |
| 2 | 0.462 (.011) | 0.723 (.019) | 0.141 (.004) | 30 |
| 7 | 0.473 (.013) | 0.665 (.022) | 0.125 (.004) | 30 |
| 11 | 0.399 (.007) | 0.760 (.022) | 0.112 (.003) | 30 |
| 20 | 0.480 (.010) | 0.637 (.023) | 0.116 (.004) | 30 |
| 41 | 0.485 (.009) | 0.650 (.022) | 0.128 (.004) | 30 |
| 50 | 0.540 (.023) | 0.554 (.015) | 0.126 (.004) | 30 |

Table 7.    Cations in Spruce needles, September 1984
            (% dry wt. Mean ±1 S.E.) N=Sample size

| Bog # | K | Ca | Mg | N |
|---|---|---|---|---|
| 101 | 1.229 (.046) | 0.288 (.015) | 0.085 (.003) | 24 |
| 102 | 1.250 (.035) | 0.310 (.016) | 0.084 (.002) | 24 |
| 21 | 0.590 (.001) | 0.394 (.016) | 0.110 (.003) | 24 |
| 22 | 0.567 (.018) | 0.380 (.017) | 0.105 (.003) | 24 |
| 40 | 0.552 (.016) | 0.278 (.015) | 0.075 (.003) | 24 |
| 2 | 1.399 (.033) | 0.410 (.017) | 0.089 (.002) | 24 |
| 7 | 1.443 (.039) | 0.300 (.021) | 0.086 (.003) | 24 |
| 11 | 0.474 (.012) | 0.363 (.021) | 0.091 (.003) | 24 |
| 20 | 0.548 (.016) | 0.343 (.018) | 0.105 (.004) | 24 |
| 41 | 0.607 (.020) | 0.353 (.019) | 0.084 (.002) | 24 |
| 50 | 0.569 (.015) | 0.330 (.020) | 0.097 (.005) | 24 |

## NESTED ANALYSIS OF VARIANCE

We conducted 28 nested ANOVA´s for each cation in each
species for each sampling date. For purposes of clarity, we list
the results for tests in which certain replicate bogs were
removed to give a balanced design; this way recognizing patterns
is simplified. Tables 8 through 11 show the significance of the F
statistic, that is, the probability that the differences observed
between categories are greater than those that might be arrived
at by chance alone. Values where $P<.05$ are noted and were used as
our level of significance.

Certain results are noteworthy. Each time that Bog 11 is
removed in the nested ANOVA analysis for spruce potassium (to
keep the design balanced among the four treatments), differences
among the ELF categories are significant. The removal of Bog 11
reduces the variation within the INTERMEDIATE group. Results are
also significant when Bog 40 and Bog 7 are removed in tests for
spruce calcium. Bog 40 removal also resulted in significant
differences for spruce magnesium. It is more difficult to
understand why the removal of these bogs produce significant
results.

For leatherleaf, we found no significant results from the
analysis for June 1984. Removal of Bogs 21 and 11 together
resulted in significant results for July magnesium concentrations
in leatherleaf. Only one nested ANOVA out of 84 for cations in
September leatherleaf showed significant results (potassium for

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Table 8.   Results of Nested Analysis of Variance
for Cations in Leatherleaf leaves, June,
1984.   Significance of F statistic presented
for analyses in which combinations of
ANTENNA, INTERMEDIATE, BACKGROUND, and GROUND
bogs have been excluded. (* indicated P < .05 )

| Bogs Excluded | | | Significance of F (P < _ ) | | |
|---|---|---|---|---|---|
| ANT | INT | BKG | K | Ca | Mg |
| 22 | 7 | 41 | .538 | .485 | .647 |
| 22 | 11 | 41 | .791 | .735 | .533 |
| 21 | 7 | 20 | .379 | .378 | .737 |
| 40 | 11 | 20 | .309 | .696 | .672 |
| 40 | 7 | 50 | .090 | .222 | .210 |
| 40 | 11 | 50 | .267 | .454 | .127 |
| 21 | 11 | 50 | .563 | .471 | .103 |
| 40 | 7 | 41 | .104 | .578 | .531 |
| 22 | 2 | 20 | .812 | .657 | .936 |
| 40 | 2 | 20 | .284 | .772 | .862 |
| 22 | 11 | 50 | .652 | .331 | .225 |
| 22 | 7 | 50 | .421 | .145 | .304 |
| 21 | 7 | 41 | .445 | .591 | .567 |
| 21 | 2 | 20 | .711 | .787 | .903 |
| 21 | 2 | 41 | .854 | .904 | .805 |
| 21 | 2 | 50 | .588 | .444 | .084 |
| 21 | 7 | 50 | .303 | .228 | .168 |
| 21 | 11 | 20 | .655 | .709 | .643 |
| 21 | 11 | 41 | .764 | .847 | .441 |
| 22 | 11 | 20 | .719 | .595 | .720 |
| 22 | 7 | 20 | .483 | .298 | .802 |
| 22 | 2 | 41 | .862 | .768 | .954 |
| 22 | 2 | 50 | .734 | .298 | .231 |
| 40 | 11 | 41 | .308 | .832 | .421 |
| 40 | 7 | 20 | .116 | .372 | .755 |
| 40 | 2 | 41 | .262 | .888 | .646 |
| 40 | 2 | 50 | .228 | .428 | .077 |
| 101,102 (GROUND) | | | .261 | .283 | .746 |

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Table 9.    Results of Nested Analysis of Variance for
            Cations in Leatherleaf leaves,  July, 1984.
            Significance of  F statistic presented for
            analyses in which combinations of ANTENNA,
            INTERMEDIATE, BACKGROUND and GROUND bogs have
            been excluded.    ( * indicates P < .05 )

| Bogs Excluded | | | Significance of F (P < _ ) | | |
|---|---|---|---|---|---|
| ANT | INT | BKG | K | CA | MG |
| 21 | 2 | 41 | .146 | .394 | .072 |
| 21 | 2 | 20 | .120 | .398 | .070 |
| 21 | 11 | 50 | .336 | .392 | .029 * |
| 22 | 11 | 41 | .427 | .401 | .310 |
| 40 | 11 | 20 | .484 | .405 | .264 |
| 40 | 11 | 50 | .480 | .410 | .284 |
| 40 | 7 | 41 | .140 | .421 | .442 |
| 22 | 2 | 20 | .172 | .416 | .240 |
| 40 | 2 | 20 | .161 | .416 | .243 |
| 40 | 7 | 50 | .100 | .432 | .365 |
| 22 | 7 | 41 | .179 | .421 | .442 |
| 22 | 11 | 50 | .390 | .410 | .282 |
| 22 | 7 | 50 | .142 | .432 | .364 |
| 21 | 7 | 41 | .140 | .402 | .141 |
| 21 | 7 | 20 | .126 | .407 | .124 |
| 21 | 2 | 50 | .115 | .402 | .077 |
| 21 | 7 | 50 | .108 | .411 | .132 |
| 21 | 11 | 20 | .359 | .388 | .025 * |
| 21 | 11 | 41 | .372 | .385 | .010 * |
| 22 | 11 | 20 | .413 | .405 | .262 |
| 22 | 7 | 20 | .164 | .426 | .348 |
| 22 | 2 | 41 | .203 | .412 | .301 |
| 22 | 2 | 50 | .169 | .421 | .254 |
| 40 | 11 | 41 | .514 | .401 | .313 |
| 40 | 7 | 20 | .115 | .426 | .349 |
| 40 | 2 | 41 | .230 | .412 | .305 |
| 40 | 2 | 50 | .180 | .421 | .257 |
| 101,102 (GROUND) | | | .514 | .115 | .118 |

Table 10.    Results of Nested Analysis of Variance for
            Cations in Leatherleaf leaves, September,
            1984.  Significance of F statistic presented
            for analyses in which combinations of ANTENNA,
            INTERMEDIATE, BACKGROUND, and GROUND bogs
            have been excluded. ( * indicates P < .05 )

Bogs Excluded          Significance of F   (P < _ )

| ANT | INT | BKG | K | | Ca | Mg |
|---|---|---|---|---|---|---|
| 21 | 2 | 20 | .254 | | .352 | .135 |
| 21 | 2 | 41 | .274 | | .286 | .233 |
| 21 | 7 | 20 | .187 | | .133 | .657 |
| 21 | 7 | 41 | .204 | | .096 | .643 |
| 22 | 11 | 41 | .441 | | .384 | .640 |
| 22 | 7 | 50 | .155 | | .179 | .899 |
| 22 | 11 | 50 | .244 | | .638 | .713 |
| 22 | 7 | 41 | .207 | | .152 | .863 |
| 40 | 11 | 20 | .176 | | .376 | .881 |
| 40 | 7 | 50 | .070 | | .099 | .882 |
| 40 | 11 | 50 | .040 | * | .575 | .683 |
| 40 | 2 | 20 | .160 | | .370 | .458 |
| 21 | 11 | 50 | .234 | | .397 | .279 |
| 22 | 2 | 20 | .257 | | .438 | .545 |
| 40 | 7 | 41 | .123 | | .099 | .840 |
| 21 | 2 | 50 | .221 | | .381 | .282 |
| 21 | 7 | 50 | .152 | | .076 | .678 |
| 21 | 11 | 20 | .391 | | .371 | .218 |
| 21 | 11 | 41 | .434 | | .291 | .228 |
| 22 | 11 | 20 | .399 | | .470 | .870 |
| 22 | 7 | 20 | .190 | | .198 | .964 |
| 22 | 2 | 41 | .276 | | .366 | .538 |
| 22 | 2 | 50 | .223 | | .564 | .584 |
| 40 | 11 | 41 | .208 | | .282 | .598 |
| 40 | 7 | 20 | .110 | | .143 | .965 |
| 40 | 2 | 41 | .174 | | .292 | .450 |
| 40 | 2 | 50 | .113 | | .527 | .503 |
| 101,102 (GROUND) | | | .080 | | .090 | .957 |

Table 11. Results of Nested Analysis of Variance for Cations in Spruce needles, September, 1984. Significance of F statistic presented for analyses in which combinations of ANTENNA, INTERMEDIATE, BACKGROUND, and GROUND bogs have been excluded. (* indicates P < .05 )

| Bogs Excluded | | | Significance of F (P < __ ) | | | | | |
|---|---|---|---|---|---|---|---|---|
| ANT | INT | BKG | K | | Ca | | Mg | |
| 21 | 2 | 41 | .273 | | .841 | | .582 | |
| 21 | 7 | 20 | .272 | | .355 | | .949 | |
| 21 | 2 | 20 | .289 | | .819 | | .960 | |
| 21 | 7 | 41 | .256 | | .349 | | .588 | |
| 22 | 11 | 41 | .000 | * | .826 | | .664 | |
| 22 | 7 | 50 | .275 | | .417 | | .914 | |
| 22 | 11 | 50 | .000 | * | .797 | | .904 | |
| 22 | 7 | 41 | .263 | | .423 | | .691 | |
| 40 | 11 | 20 | .000 | * | .327 | | .032 | * |
| 40 | 7 | 50 | .279 | | .027 | * | .139 | |
| 40 | 11 | 50 | .000 | * | .319 | | .127 | |
| 40 | 2 | 20 | .302 | | .110 | | .037 | * |
| 21 | 11 | 50 | .000 | * | .768 | | .892 | |
| 22 | 2 | 20 | .298 | | .834 | | .948 | |
| 40 | 7 | 41 | .267 | | .027 | * | .010 | * |
| 21 | 2 | 50 | .284 | | .756 | | .898 | |
| 21 | 7 | 50 | .267 | | .339 | | .896 | |
| 21 | 11 | 20 | .000 | * | .798 | | .959 | |
| 21 | 11 | 41 | .000 | * | .806 | | .568 | |
| 22 | 11 | 20 | .000 | * | .821 | | .945 | |
| 22 | 7 | 20 | .280 | | .430 | | .945 | |
| 22 | 2 | 41 | .280 | | .850 | | .678 | |
| 22 | 2 | 50 | .293 | | .785 | | .910 | |
| 40 | 11 | 41 | .000 | * | .317 | | .010 | * |
| 40 | 7 | 20 | .285 | | .033 | * | .033 | * |
| 40 | 2 | 41 | .284 | | .102 | | .013 | * |
| 40 | 2 | 50 | .297 | | .096 | | .138 | |
| 101,102 (GROUND) | | | .159 | | .942 | | .751 | |

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the balanced design with Bogs 40,11 and 50 removed). We conclude that such an isolated significant result could have occurred by chance alone.

SIMPLE LINEAR REGRESSION

To understand the significant results from the ANOVA analyses, we conducted simple linear regression analyses between the mean plant cation values and the environmental and ELF field variables associated with the 66 subplots (six per site times eleven sites). These results are presented as Pearson correlation coefficients in Tables 12-15. Several correlations proved to be significant; however, with large sample sizes, correlation coefficients do not have to be particularly large in order to be significant. The largest correlationr was found to be $r=0.552$; but with this only 30.4% of the variance associated with the cation data could be explained. Most significant values for r ranged between .25 and .35. Although these correlations are significant, they account for very little of the variance in foliar cation concentration found in the bogs.

MULTIPLE REGRESSION

In an attempt to reduce the unexplained variance in the nutrient data sets, we conducted forward stepwise multiple regression analysis on all September spruce cations and on July leatherleaf magnesium concentration. Those variables showed more

Table 12. Pearson correlation coefficients (r) for cations in June, 1984 Leatherleaf leaves and 1984 environmental and ELF parameters found in the bogs. N = 66, * indicates P < .05 in a two-tailed test.

| Env/ELF Var. | K | Ca | Mg |
|---|---|---|---|
| JUNT | -.068 | .210 | -.072 |
| JUNPH | -.067 | -.029 | -.105 |
| JUNSPC | -.053 | -.025 | .066 |
| JUNCA | -.070 | -.034 | -.073 |
| JUNMG | -.036 | .053 | -.119 |
| JUNK | .201 | -.235 | -.110 |
| JUNAB | -.128 | .199 | -.142 |
| JUNOM | -.108 | -.068 | -.047 |
| JULZ | -.142 | .045 | -.050 |
| JULT | .048 | .188 | .058 |
| JULPH | -.062 | -.177 | -.089 |
| JULSPC | -.145 | .053 | .153 |
| JULEH | -.131 | .208 | .091 |
| JULCA | -.068 | -.001 | -.141 |
| JULMG | -.040 | -.138 | -.030 |
| JULK | .109 | -.245* | -.193 |
| JULAB | -.180 | -.198 | -.135 |
| JULOM | -.123 | -.138 | -.169 |
| AGZ | -.138 | -.163 | .129 |
| AGT | -.058 | .178 | .004 |
| AGPH | -.021 | .009 | -.116 |
| AGSPC | -.075 | -.125 | -.032 |
| AGEH | -.041 | -.216 | .286* |
| AGCA | -.047 | -.023 | -.121 |
| AGMG | -.061 | -.037 | -.135 |
| AGK | .035 | -.163 | -.230 |
| AGAB | -.181 | -.151 | .143 |
| AGOM | -.126 | -.031 | -.071 |

| Env/ELF Var. | K | Ca | Mg |
|---|---|---|---|
| SEPZ | -.111 | -.054 | .264* |
| SEPT | .013 | .134 | .097 |
| SEPPH | .011 | .028 | -.077 |
| SEPSPC | -.112 | -.078 | .045 |
| SEPEH | .101 | .163 | .038 |
| SEPCA | .050 | -.058 | .130 |
| SEPMG | -.038 | -.106 | -.127 |
| SEPAB | -.192 | -.194 | -.128 |
| SEPOM | -.034 | -.270* | -.086 |
| SEPSI | -.164 | -.044 | .012 |
| OCTZ | -.096 | -.114 | .099 |
| OCTT | .012 | .016 | -.049 |
| OCTPH | -.013 | -.011 | -.106 |
| OCTSPC | -.096 | -.018 | -.118 |
| OCTEH | -.132 | .002 | -.022 |
| OCTCA | -.055 | -.054 | -.117 |
| OCTMG | -.045 | -.033 | -.106 |
| OCTAB | -.174 | -.176 | -.086 |
| OCTOM | -.108 | -.052 | -.013 |
| OCTSI | -.099 | .302* | .188 |
| AIR | -.094 | -.038 | -.232 |
| EARTH | -.102 | -.040 | .219 |
| MAG | -.075 | -.278* | -.165 |

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Table 13. Pearson correlation coefficients (r) for cations in July, 1984, Leatherleaf leaves and 1984 environmental and ELF parameters found in the bogs. N = 66, * indicates P < .05 in a two-tailed test.

| Env/ELF Var. | K | Ca | Mg |
|---|---|---|---|
| JUNT | .043 | -.042 | -.0004 |
| JUNPH | -.202 | -.062 | -.182 |
| JUNSPC | .060 | .032 | -.197 |
| JUNCA | .107 | -.158 | -.184 |
| JUNMG | -.127 | -.122 | -.233 |
| JUNK | .356 * | -.172 | .057 |
| JUNAB | .147 | -.180 | -.189 |
| JUNOM | .110 | -.161 | -.218 |
| JULZ | .276 * | -.196 | -.037 |
| JULT | .039 | -.048 | .045 |
| JULPH | .012 | -.126 | -.149 |
| JULSPC | -.054 | .026 | -.110 |
| JULEH | .191 | .076 | .002 |
| JULCA | .070 | -.126 | -.152 |
| JULMG | .095 | -.210 | -.006 |
| JULK | .171 | .012 | -.046 |
| JULAB | -.097 | -.149 | -.259 * |
| JULOM | -.009 | -.054 | -.017 |
| AGZ | .187 | .009 | .041 |
| AGT | -.221 | .025 | -.028 |
| AGPH | -.014 | -.116 | -.086 |
| AGSPC | .096 | -.030 | -.103 |
| AGEH | .216 | -.229 | -.164 |
| AGCA | .118 | -.190 | -.135 |
| AGMG | .129 | -.196 | -.127 |
| AGK | .064 | -.058 | -.005 |
| AGAB | .095 | -.153 | -.234 |
| AGOM | .095 | -.105 | -.239 |

| Env/ELF Var. | K | Ca | Mg |
|---|---|---|---|
| SEPZ | .092 | -.045 | .000 |
| SEPT | -.175 | -.022 | -.126 |
| SEPPH | .055 | -.064 | .003 |
| SEPSPC | .050 | -.001 | -.072 |
| SEPEH | .077 | .216 | -.108 |
| SEPCA | .127 | -.173 | -.146 |
| SEPMG | .071 | -.251 * | -.150 |
| SEPAB | .148 | -.232 | -.255 * |
| SEPOM | -.073 | .011 | -.010 |
| SEPSI | .124 | -.131 | .175 |
| OCTZ | .122 | .005 | -.101 |
| OCTT | .225 | -.115 | -.031 |
| OCTPH | .110 | -.212 | -.182 |
| OCTSPC | .032 | .065 | -.029 |
| OCTEH | .062 | -.241 * | -.223 |
| OCTCA | .0001 | -.245 * | -.281 |
| OCTMG | .018 | -.242 * | -.201 |
| OCTAB | .063 | -.170 | -.327 * |
| OCTOM | .039 | -.106 | -.313 * |
| OCTSI | -.042 | .336 * | -.017 |
| AIR | .135 | -.082 | .103 |
| EARTH | .135 | -.120 | .067 |
| MAG | -.310 * | -.214 | -.306 * |

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Table 14. Pearson correlation coefficients (r) for cations in September, 1984, Leatherleaf leaves and 1984 environmental and ELF parameters found in the bogs. N = 66, * indicates P < .05 in a two-tailed test.

| Env/ELF Var. | K | Ca | Mg | Env/ELF Var. | K | Ca | Mg |
|---|---|---|---|---|---|---|---|
| JUNT | -.127 | .314 * | .149 | SEPZ | -.076 | -.014 | -.026 |
| JUNPH | .143 | .033 | -.041 | SEPT | -.151 | .081 | -.084 |
| JUNSPC | -.341 * | .179 | -.004 | SEPPH | .384 * | -.041 | -.048 |
| JUNCA | .247 * | .090 | .031 | SEPSPC | -.269 * | .082 | -.081 |
| JUNCA | -.022 | .248 * | -.044 | SEPEH | .030 | -.078 | -.048 |
| JUNK | .054 | -.233 | -.132 | SEPCA | .224 | -.011 | -.038 |
| JUNAB | .219 | .149 | .066 | SEPMG | .262 * | .045 | .032 |
| JUNOM | .033 | .297 * | .088 | SEPAB | .127 | .184 | -.049 |
| JULZ | -.267 * | .165 | -.234 | SEPOM | .122 | .006 | .166 |
| JULT | -.061 | .057 | .016 | SEPSI | .026 | .315 * | .124 |
| JULPH | .208 | .156 | .014 | OCTZ | -.039 | .050 | -.155 |
| JULSPC | -.278 * | .170 | .085 | OCTT | -.060 | -.068 | -.137 |
| JULEH | -.365 * | .056 | -.153 | OCTPH | .208 | .050 | -.130 |
| JULCA | .183 | .129 | .045 | OCTSPC | -.307 * | .074 | -.061 |
| JULMG | .257 * | -.084 | .047 | OCTEH | -.013 | .103 | -.054 |
| JULK | .180 | .015 | -.100 | OCTCA | .090 | .048 | -.082 |
| JULAB | .162 | .197 | .032 | OCTMG | .200 | .086 | -.018 |
| JULOM | .077 | .156 | .186 | OCTAB | .156 | .127 | -.203 |
| AG2 | .116 | .018 | .005 | OCTOM | -.012 | .271 * | -.081 |
| AGT | -.146 | .328 * | .222 | OCTSI | .044 | .141 | -.078 |
| AGPH | .291 * | .003 | .012 | AIR | .257 * | .091 | .194 |
| AGSPC | -.058 | .073 | -.144 | EARTH | .272 * | .101 | .196 |
| AGEH | .018 | -.227 | -.105 | MAG | .144 | -.135 | -.120 |
| AGCA | .149 | .118 | .054 | | | | |
| AGMG | .220 | .103 | .051 | | | | |
| AGK | .123 | -.066 | -.098 | | | | |
| AGAB | .132 | .207 | -.006 | | | | |
| AGOM | .007 | .254 * | -.016 | | | | |

Table 15. Pearson correlation coefficients (r) for cations in 1984 Spruce needles and 1984 environmental and ELF parameters found in the bogs. N = 66, * indicates P < .05 in a two-tailed test.

| Env/ELF Var. | K | Ca | Mg |
|---|---|---|---|
| JUNT | .552 * | -.163 | -.413 * |
| JUNPH | -.209 | .234 | .159 |
| JUNSPC | .059 | .054 | -.064 |
| JUNCA | .124 | .136 | -.224 |
| JUNMG | .071 | .045 | .057 |
| JUNK | .113 | -.210 | -.142 |
| JUNAB | .248 | -.080 | -.046 |
| JUNOM | .364 * | .092 | .003 |
| JULZ | -.006 | -.062 | -.142 |
| JULT | .391 * | -.156 | -.481 * |
| JULPH | -.154 | .245 * | .314 * |
| JULSPC | .307 * | -.034 | -.089 |
| JULEH | .393 * | -.179 | -.252 * |
| JULCA | .256 * | .021 | .075 |
| JULMG | .030 | .092 | .166 |
| JULK | .038 | -.059 | .005 |
| JULAB | .180 | .002 | .040 |
| JULOM | .113 | .211 | .167 |
| AGZ | .092 | .163 | .234 |
| AGT | .279 * | .063 | -.263 * |
| AGPH | .094 | -.054 | -.023 |
| AGSPC | .259 * | -.057 | -.096 |
| AGEH | .055 | .035 | .134 |
| AGCA | .357 * | -.031 | -.033 |
| AGMG | .298 * | -.065 | -.023 |
| AGK | .122 | -.308 * | -.306 * |
| AGAB | .272 * | -.084 | -.047 |
| AGOM | .398 * | -.010 | -.051 |

| Env/ELF Var. | K | Ca | Mg |
|---|---|---|---|
| SEPZ | .129 | .126 | .001 |
| SEPT | .060 | .010 | -.342 * |
| SEPPH | .146 | -.115 | -.035 |
| SEPSPC | .024 | .098 | .044 |
| SEPEH | .018 | -.082 | -.053 |
| SEPCA | .229 | -.043 | .001 |
| SEPMG | .201 | -.042 | .051 |
| SEPAB | .296 * | -.039 | -.014 |
| SEPOM | -.191 | .227 | .289 * |
| SEPSI | .446 * | .141 | .048 |
| OCTZ | .002 | .018 | .097 |
| OCTT | .197 | -.267 * | -.308 |
| OCTPH | .124 | -.093 | -.088 |
| OCTSPC | .057 | .144 | .073 |
| OCTEH | .110 | .005 | -.090 |
| OCTCA | .159 | .037 | .033 |
| OCTMG | .226 | .023 | .058 |
| OCTAB | .130 | .099 | .076 |
| OCTOM | .124 | .244 | .196 |
| OCTSI | -.016 | .154 | .186 |
| AIR | .342 * | -.243 * | -.124 |
| EARTH | .354 * | -.230 | -.135 |
| MAG | -.334 * | -.153 | -.141 |

than one significant result in the nested ANOVA model. We used the Pearson correlation coefficient matrix of environmental and ELF variables to generate a list of independent variables; the parameters chosen for use were those uncorrelated with any other variable and those variables that were autocorrelated with and therefore representative of other variables using a criterion of $r=.80$ (see Table 2). The ELF parameters - air and earth electric field intensity and magnetic field intensity- were independent (uncorrelated) of each other and the environmental data. We used a logarithmic transformation on the ELF field data to make the variance more homogenous (homoscedastic). We also eliminated environmental variables measured during the months following the foliar sampling (i.e. October environmental data in the analysis of September foliar nutrient data and August-October environmental data in the analysis of July foliar nutrient data). The results of our stepwise multiple regression analyses are shown in Table 16.

In no instance was the concentration of a cation in the interstitial water (e.g. July magnesium in water and July foliar magnesium concentration) selected as an important parameter explaining the variance of the concentration of that cation in the foliar tissue. Some of the parameters selected, such as specific conductance and pH may indicate the general ionic condition of the interstitial water in the root zone. Depth and Eh are parameters related to the aeration of the root zone; redox conditions may affect root function and plant nutrient status.

Of the four stepwise regressions conducted, only the

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Table 16. Results of stepwise regressions for leaf cations with environmental and ELF parameters in 1984. N = 66, B = regression coefficient, partial r = partial correlation coefficient, T statistic tests B = 0.

| Dependent Variable | Independent Vars. Selected | B | partial r | T | sig. T |
|---|---|---|---|---|---|
| Spruce K September | LOGAIR | 1.791 | 0.9374 | 20.144 | .00001 |
| | LOGMAG | -1.701 | -0.9101 | -16.439 | .00001 |
| | JULYZ | -0.1221 | -0.6096 | -5.755 | .00001 |
| | SEPZ | 0.0995 | 0.5125 | 4.467 | .00001 |
| | JULYSPC | 0.0700 | 0.5023 | 4.347 | .0001 |
| | JULYPH | -1.7468 | -0.4772 | -4.064 | .0002 |
| | AGSPC | 0.0288 | 0.4556 | 3.830 | .0003 |
| | JUNSPC | -0.0786 | -0.4508 | -3.780 | .0004 |
| | SEPSPC | -0.0499 | -0.3504 | -2.799 | .0070 |

CONSTANT = 14.2517

$R^2$ = .902

| Spruce Ca September | AGK | -0.4855 | -0.4722 | -4.218 | .0001 |
|---|---|---|---|---|---|
| | JUNPH | 0.6161 | 0.3434 | 2.879 | .0055 |
| | JULK | 0.5412 | 0.3385 | 2.832 | .006 |

CONSTANT = 1.2755

$R^2$ = .234

| Spruce Mg September | JULT | -0.0482 | -0.5241 | -4.885 | .00001 |
|---|---|---|---|---|---|
| | JULPH | 0.2429 | 0.3870 | 3.331 | .0015 |

CONSTANT = 1.6797

$R^2$ = .326

| Leatherleaf Mg July | LOGMAG | -0.0296 | -0.3176 | -2.658 | .0099 |
|---|---|---|---|---|---|
| | JUNSPC | -0.0071 | -0.2492 | -2.042 | .0453 |

CONSTANT = 2.124

$R^2$ = .108

September spruce potassium analysis accounted for much of the overall sample variance (Table 16). The analysis for spruce calcium selected four parameters: August K, June pH, and July K that account for 23.4% of the variance. Only two parameters, July T and July pH, were selected in the analysis of spruce magnesium and accounted for only 32.6% of the sample variance. ELF parameters were not selected in these two analyses. The leatherleaf July magnesium analysis selected two varaiables (log magnetic field and June specific conductance) which accounted for only 10.8% of the varaiance.

Results from the spruce potassium analysis were more interesting in that a large amount of the variance (90.2%) was accounted for and the variables chosen included ELF parameters. Nine parameters were selected in the analysis. The partial correlation coefficients indicate the relative importance of each in accounting for the variance in foliar potassium content among subplots. Their relative ranking is: log(air field) > log (magnetic field) > July water depth > July specific conductance > July pH > August specific conductance > June specific conductance > September specific conductance (Table 16). All of the regression coefficients (B) are significantly different from zero at the p<.01 level. A total of 90.2% of the variance is accounted by these nine variables. In a previous step of the stepwise procedure, the combination of ELF air and magnetic fields accounted for 61.5% of the variance. It is interesting to note that all of the specific conductance data collected during or previous to the September sample were selected in the regression

analysis; however, the specific conductance measurements were not found to be autocorrelated.

We plotted leaf cations versus the variables selected from the regression procedures in an attempt to better understand the results of the stepwise regression analysis (Figures 2 - 6). None of these plots exhibit any clear cut trends. However, certain pl ts are interesting because they present ambiguous patterns.

A plot of spruce potassium vs air electric field (Figure 3) shows that potassium levels in plants from Bogs 2,7 (INTERMEDIATE) and 101,102 (GROUND) were high relative to the BACKGROUND and ANTENNAE sites. However, plots of spruce potassium content with other environmental and ELF parameters show the same ambiguous pattern. Plotting spruce potassium with June water temperature (Figure 5), the variable with the highest Pearson correlation coefficient, did not help in explaining the pattern.

Plots of September spruce magnesium with environmental and ELF parameters were less ambiguous. There appears to be a negative relationship between July temperature and magnesium concentration (Figure 7). A plot of magnetic field versus magnesium concentration indicates a positive relationship (Figure 8). No clear trend emerges when leatherleaf magnesium concentration is plotted against the environmental and ELF parameters selected by multiple regression (Figure 2).

In each case in which one of the ELF parameters was selected in the stepwise regression procedure, we plotted leaf cation concentration versus the log transformed data to expand the scale since the ELF fields span two orders of magnitude in our sites.

Figure 2. Mean values for Leatherleaf foliar magnesium concentrations, plotted against ELF magnetic field data (each data point represents the mean of 5 values from a subplot within a bog). Symbols represent INTERMEDIATE ⬡ , GROUND ⬠ , CONTROL ☐ , and ANTENNA △ sites.



LL JULY,1984  Mg$^{++}$

arcsin √fraction dry wt

LOG ELF MAGNETIC FIELD
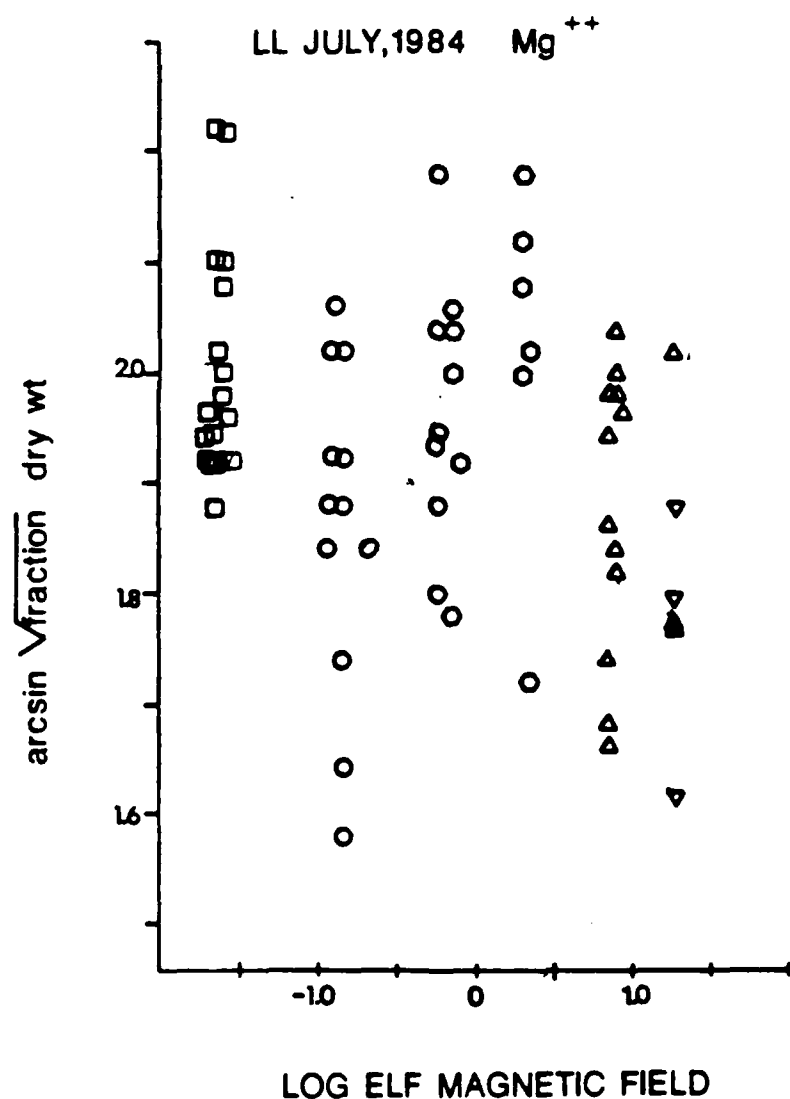
Figure 3.   Mean values for Spruce foliar potassium
concentrations, plotted against ELF electric field in air (each
data point represents the mean of 5 values from a subplot within
a bog).   Symbols represent INTERMEDIATE ◯    , GROUND ⬡    ,
CONTROL ☐    , and ANTENNA        △    sites.
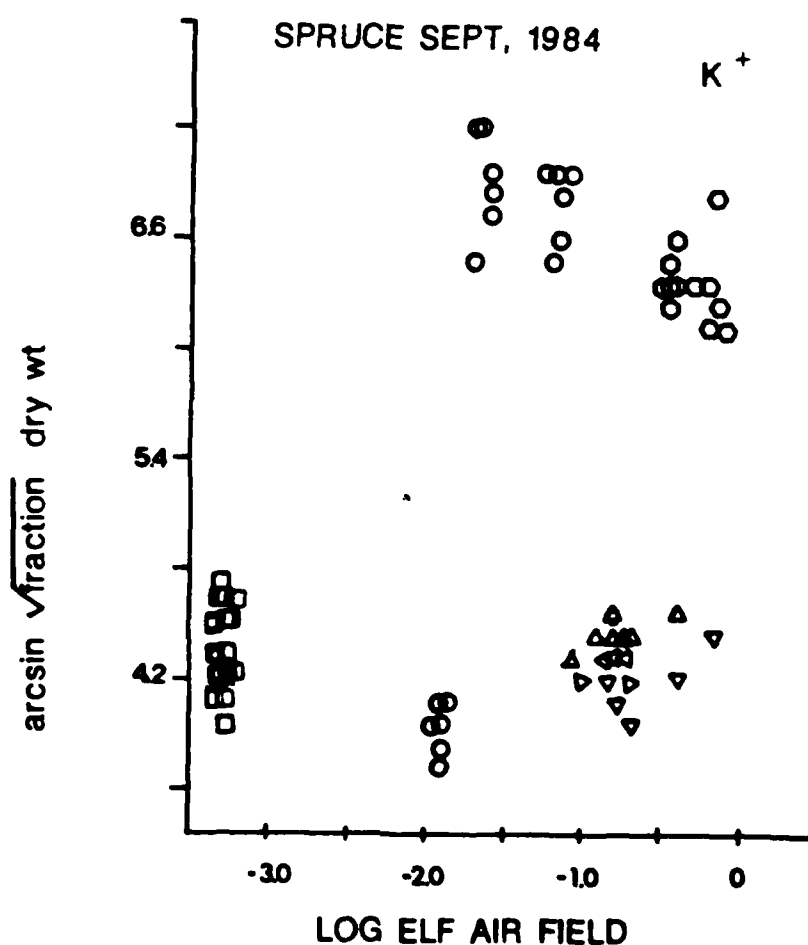
Figure 4.    Mean values for Spruce foliar potassium
concentrations, plotted against ELF magnetic field data (each
data point represents the mean of 5 values from a subplot within
a bog).    Symbols represent INTERMEDIATE  O      , GROUND  O   ,
CONTROL    ☐   , and ANTENNA      Δ      sites.



SPRUCE SEPT, 1984

K +
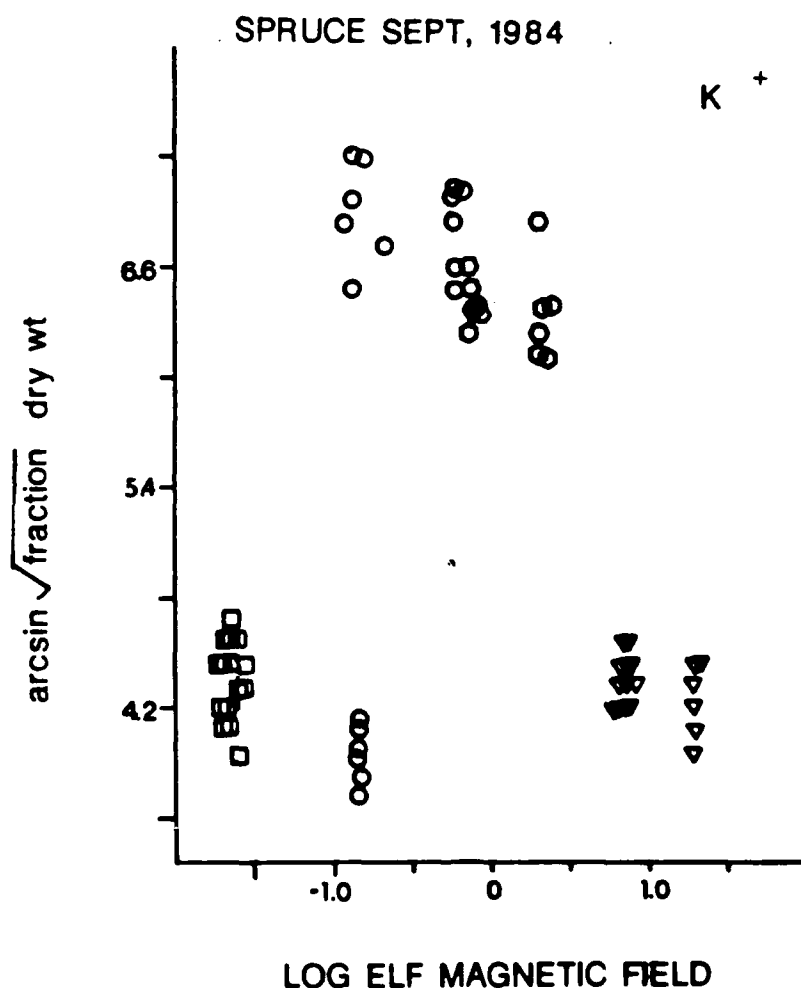
Figure 5.    Mean values for Spruce foliar potassium
concentrations, plotted against June water temperature data (each
data point represents the mean of 5 values from a subplot within
a bog).   Symbols represent INTERMEDIATE    O   , GROUND   O   ,
CONTROL   □   , and ANTENNA    △    sites.



SPRUCE   SEPT. 1984       K $^{+}$
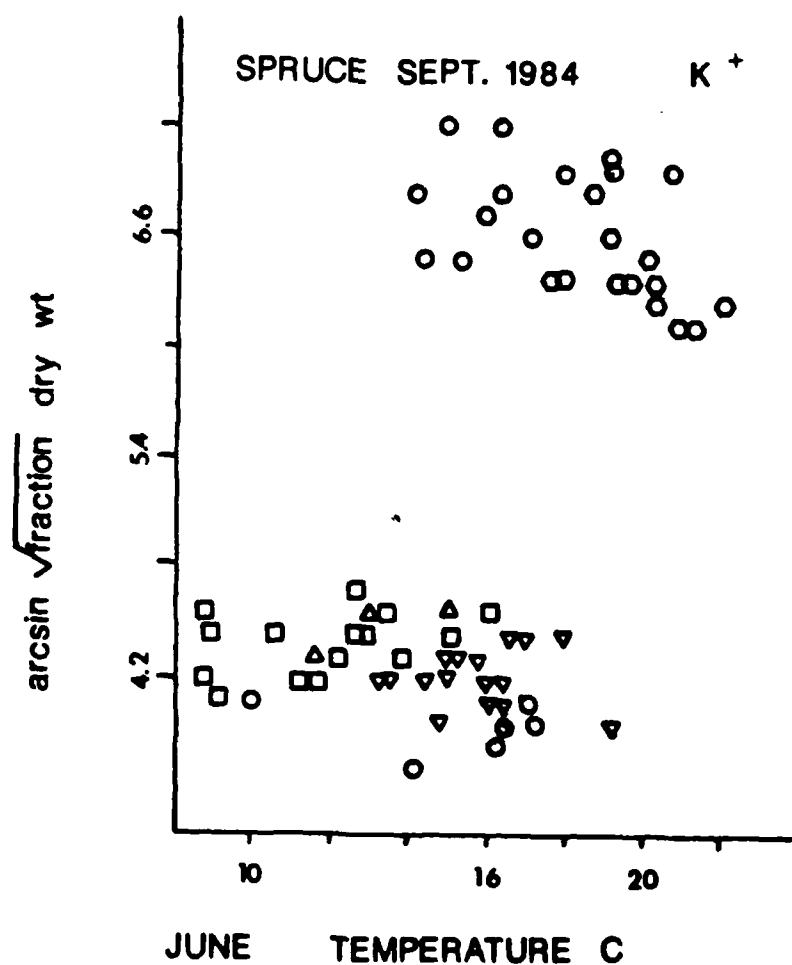
Figure 6. Mean values for Spruce foliar potassium
concentrations, plotted against July water depth in sampling
wells (each data point represents the mean of 5 values from a
subplot within a bog). Symbols represent INTERMEDIATE ○ ,
GROUND ⬡ , CONTROL ☐ , and ANTENNA △ sites.

SPRUCE SEPT, 1984          K +

JULY DEPTH TO WATER TABLE (CM)
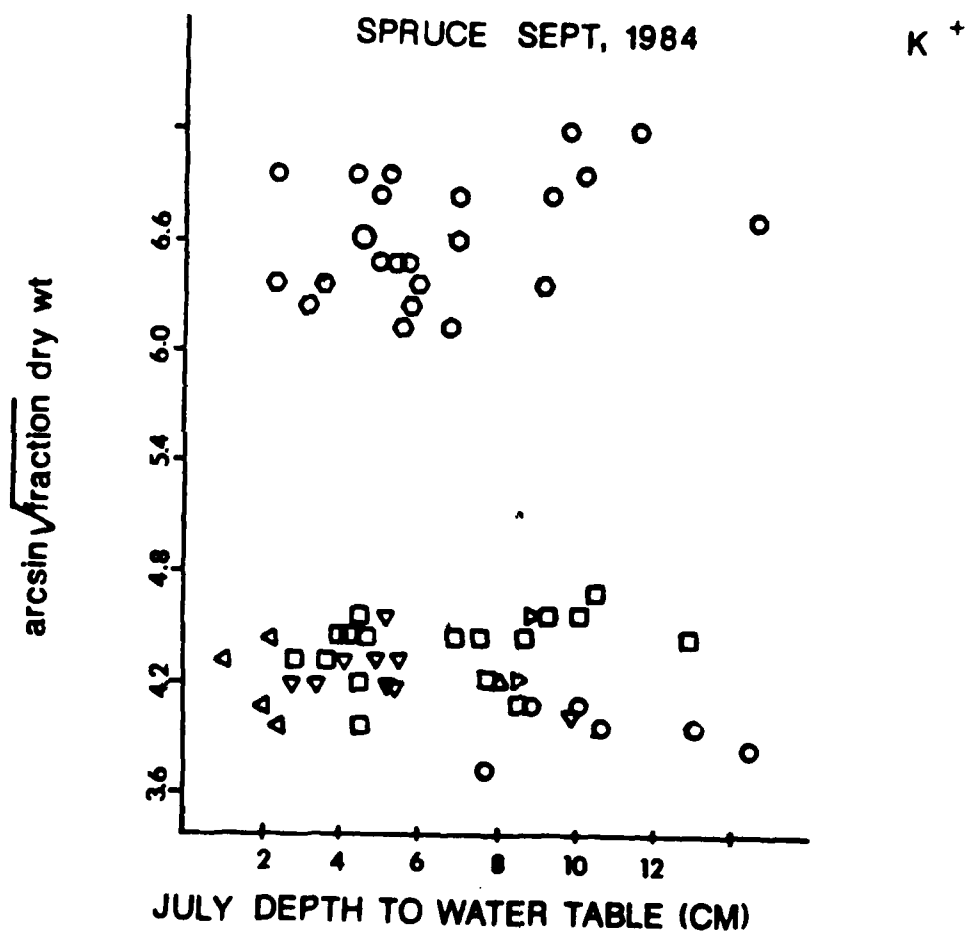
Figure 7.    Mean values for Spruce foliar magnesium
concentrations, plotted against July water temperature data (each
data point represents the mean of 5 values from a subplot within
a bog).   Symbols represent INTERMEDIATE  ○   , GROUND  ⬡  ,
CONTROL  ☐  , and ANTENNA  △     sites.
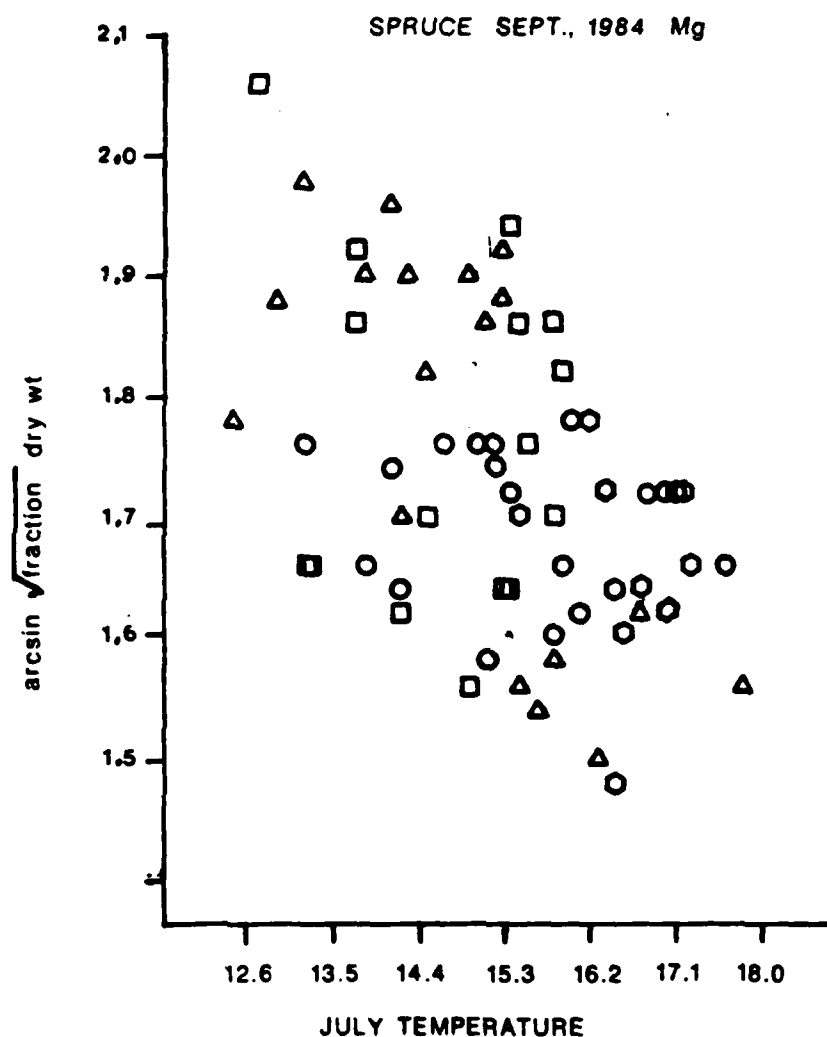
Figure 8.    Mean values for Spruce foliar magnesium
concentrations, plotted against ELF magnetic field data (each
data point represents the mean of 5 values from a subplot within
a bog).   Symbols represent INTERMEDIATE  ○   , GROUND  ⬡  ,
CONTROL  ☐  , and ANTENNA  △   sites.



SPRUCE  SEPT., 1984   Mg
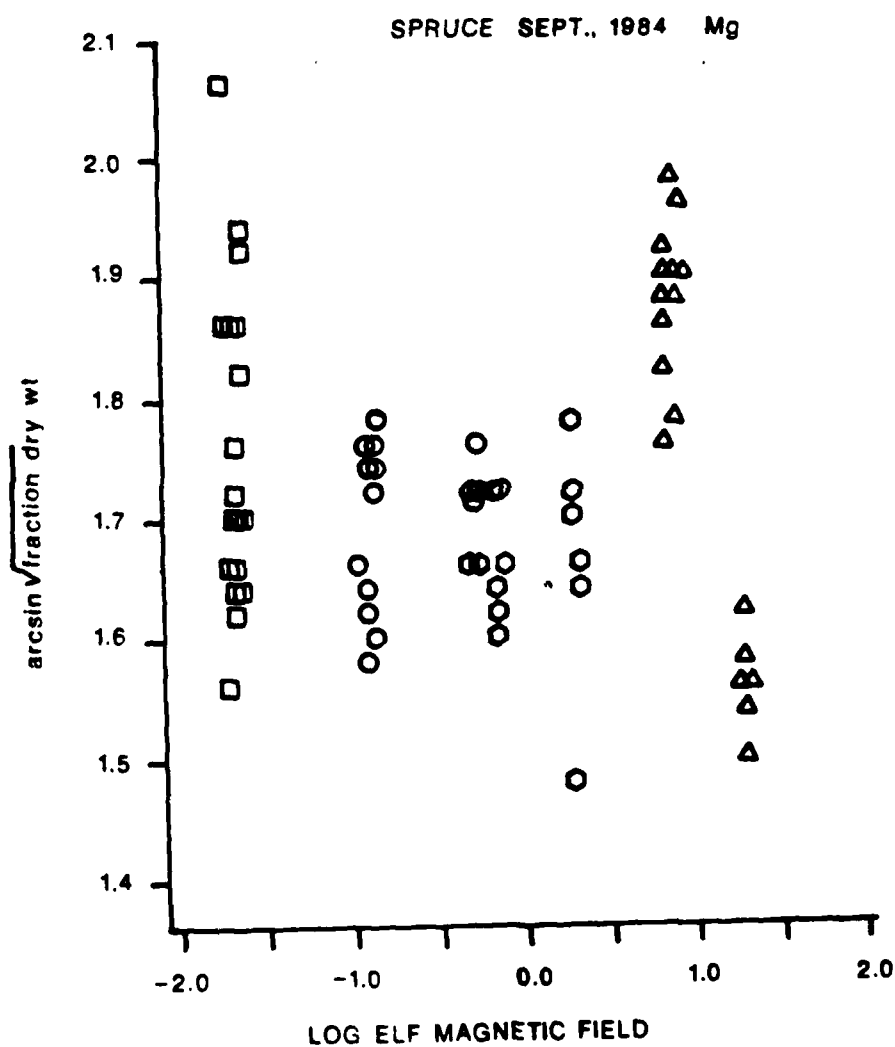
In each case, there was no apparent pattern even though multivariate analyses suggest that these parameters are important in explaining the test data.

## DISCRIMINANT ANALYSIS

Each cation can be examined separately in our statistical analyses. However, plant cells must also maintain a balance between nutrients. The behavior of one element may be influenced by the presence of other nutrients, thus it may not be appropriate to examine our data set element by element. More powerful multivariate techniques exist that can compare groups in terms of many variables. The use of multivariate techniques such as discriminant analysis makes it possible for us to use all of the cation data for a species as an exploratory technique to provide insight into a complex data set.

Discriminant analysis makes use of a set of dependent variables ( in this case foliar nutrients) to distinguish between groups. The set of dependent variables are mathematically combined and linear combinations are derived in such a manner as to maximize the separation of groups consistent with minimizing the variation within groups (Tatsuoka 1971). Groups were defined two ways: 1) as the data from each of the eleven sites for a single species from a single collection date and 2) the data from each of the four levels in our experimental design from a single species and a single collection date. The groupings are plotted in a parsimonious multidimensional space. Two axes are usually

sufficient to examine the data. The separation of groups along each axis can be statistically tested and the variables most important in the separation of groups identified.

Most analyses for leatherleaf (Fig. 9) demonstrated considerable overlap between groups however defined. However, the results from spruce do indicate a separation between ground and intermediate sites and control and antennae sites (Fig. 10). The coefficients associated with each axis are derived from the linear combinations of nutrients and are similar to those derived in regression analysis. The data have been standardized in the analysis so an examination of the coefficients can emphasize the key nutrients helping to separate the groups. In the case of September spruce, potassium had the highest loading and contributes most to the separation of the groups. An examination of Table 7 confirms this difference in foliar potassium concentration among the bogs.

Figure 9.   Results from a discriminant analysis of eleven bog
sites, plotted on two canonical axes.   The analysis was based on
the tissue nutrient concentration (arcsin square root transformed
percent dry weight) of Leatherleaf current year, foliar tissue
collected in June, July, and September, 1984.   The plotted points
represent group centroids representing each bog.

## DISCRIMINANT ANALYSIS



LL JUNE 1984

LL JULY 1984

LL SEPT 1984

BACKGROUND ☐

ANTENNA ▽

INTERMEDIATE ○

CONTROL ○
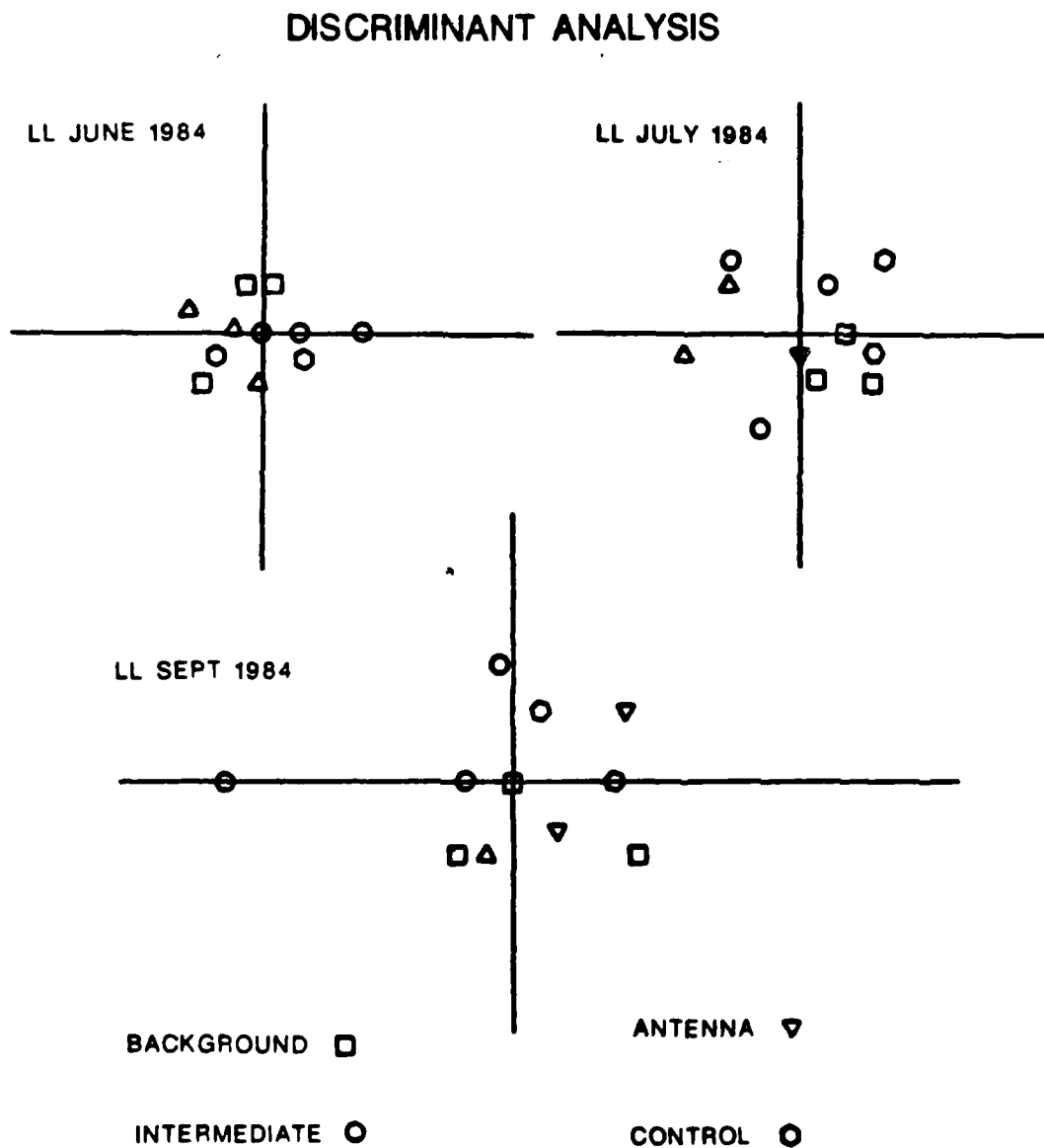
Figure 10.   Results from a discriminant analysis of eleven bog
sites plotted on two canonical axes.   The analysis was based on
the tissue nutrient concentration (arcsin square root transformed
percent dry weight) of Spruce, current year foliar tissue
collected in September, 1984.   The plotted points represent group
centroids representing each bog.



NUTRIENT BALANCE

SPRUCE SEPT, 1984

○ GROUND

△ ANTENNA

○ INTERMEDIATE

□ BACKGROUND
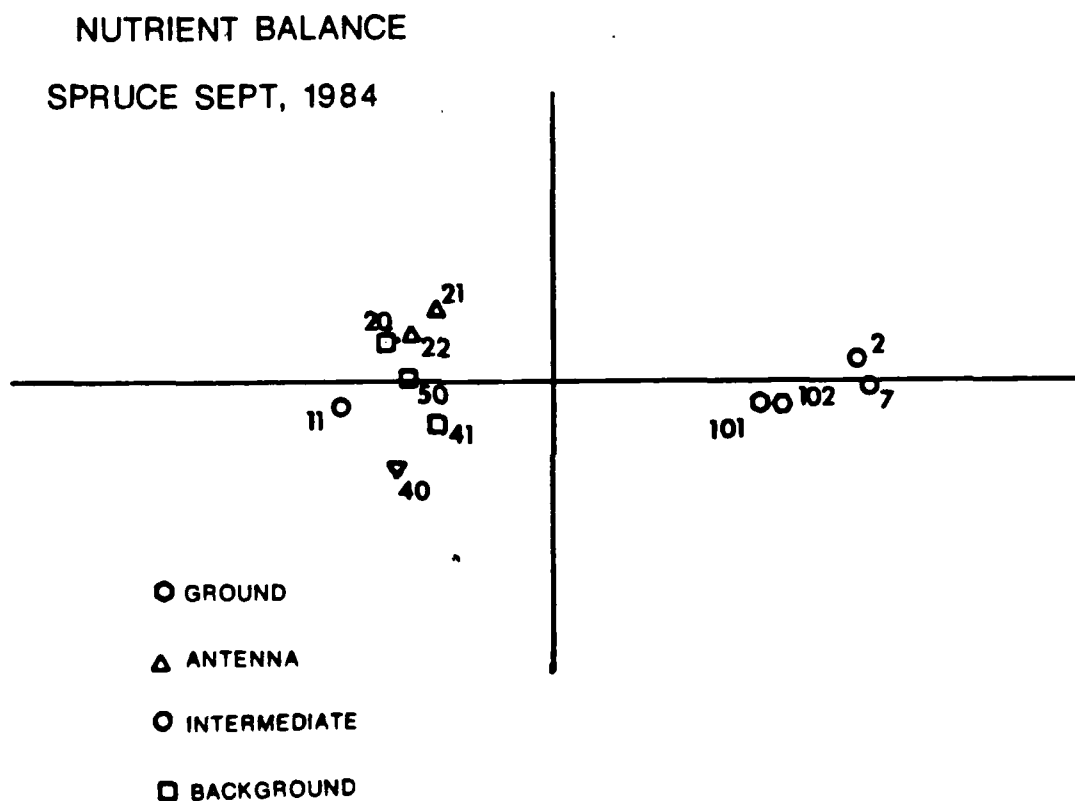
# STOMATAL RESISTANCE

Leaf stomata are regulated by many environmental and internal factors. Since ELF fields are hypothesized to operate at the membrane level, it is possible that they may affect the regulation of stomatal opening.

The status of the stomata can significantly affect photosynthesis and plant growth. For instance, water stress is well correlated with stomatal closure and reduced photosynthesis. The mineral element status of a plant may also affect stomatal opening. Hsiao (1975) has reviewed a number of studies correlating plant nutrient status with stomatal behavior. He points out that even mild potassium deficiency can restrict stomatal opening. Evidently, the mechanistic explanation is the importance of potassium in affecting the turgor of guard cells which underlies stomatal control.

We initiated a series of trials to determine a protocol for measuring stomatal opening using a steady state diffusion resistance porometer. As expected, our readings for three species (leatherleaf, labrador tea, and three- leaf false solomon's seal) were different (Table 17). However, we decided to to concentrate our efforts on one of the ericaceous shrubs, leatherleaf. Use of the herb, _Smilacina trifolia_, was restricted because of its' growth habit - near the wet ground surface which made a large number of measurements difficult. Labrador Tea is still under consideration but is not likely to be used because of the wooly trichomes on the underside of the leaf which may vary greatly

TABLE 17. A COMPARISON OF THE STOMATAL RESISTANCE (D)  (MEAN + 1 S.E.) OF THREE BOG  SPECIES OBTAINED IN BOG 41 (BACKGROUND) IN JULY 1985.

|  | D ($SCM^{-1}$) | N |
| --- | --- | --- |
| SMILICINA TRIFOLIA | 2.60+.29 | 30 |
| CHAMAEDAPHNE CALYCULATA | 2.38+.21 | 30 |
| LEDUM GROENLANDICUM | 3.23+.30 | 30 |

between leaves. Spruce was originally chosen for study but was eliminated because of the difficulty in measuring needle area. Spruce was also affected by a fungal infection which we felt might complicate the interpretation of our data. Leatherleaf is a plant with sufficient stature to avoid wetting the porometer and leaves that fit over the aperature of our cuvette and give us a constant leaf area.

Leatherleaf leaves were measured still attached to the twig and in accordance with suggestions in the LI-COR manual and from personnel at the Duke University Phytotron facility. Our initial results were encouraging and indicated no significant differences in diffussive resistance (s cm-1) between old and new leatherleaf leaves (new=1.92 + .12 old=2.01 + .12, mean + 1S.E.). However, since we intended to make measurements through the early fall we decided to restrict our measurements to new leaves. Old (second year) leaves senesce throughout their second summer which might give us spurious readings later in the season.

We also measured resistances in one site throughout the day to determine whether quantity of daylight would cause us to restrict our measurments to a particuliar time of the day. Initial sampling could not begin until late morning because most leaves were still covered by dew which would intefere with the porometer. We measured over a range from 200 to 1500 microeinsteins $m^{-2}sec^{-1}$ (PAR) and found consistent readings over the entire range (Fig. 11).

We initiated our first complete sampling in mid-August. Unfortunately, only 5 sites (3 intermediate and one each control

Figure 11.   A comparison of the stomatal resistance (s /cm) of
new 1985 Leatherleaf leaves at different light levels (uE/m$^2$/sec
PAR)
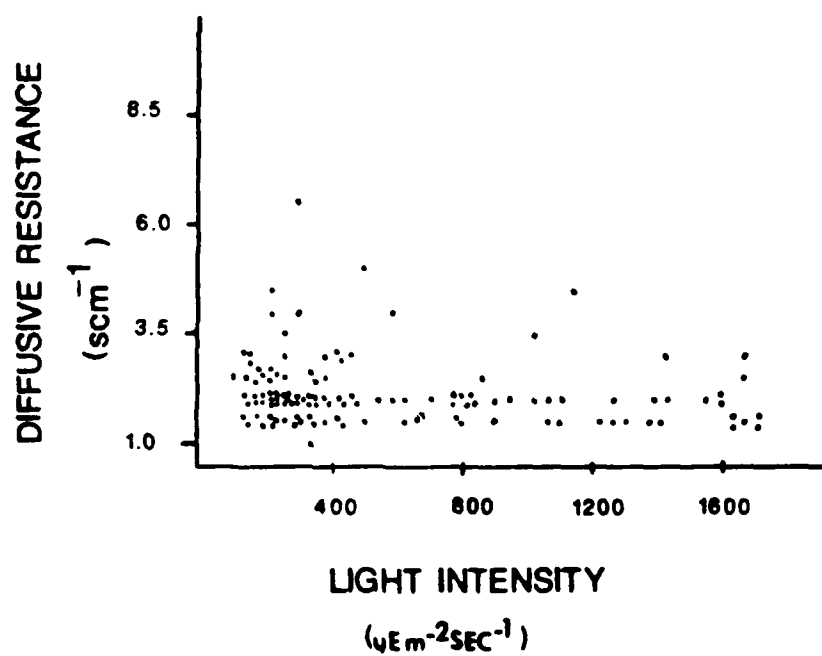
and antennae site) could be measured. A prolonged period of rainy weather prevented us from visiting the other six sites. The results from the five sites are presented in Table 18. The variation within sites is generally no greater than that found for our nutrient analyses (about 20%).

We decided to examine this incomplete data set with a single analysis of variance model to detect potential differences between sites. This analysis did detect a significant difference among sites (see Table 18). The use of a multiple means test indicated that Bog 41 measurements were higher than the other sites. An examination of the environmental data however, indicated that light readings were also much lower in this site when measurements were taken compared to the other sites (Fig. 12). Diffusive resistance readings in Bog 41 were taken late in the day after 4:00pm when light levels had dropped below 100 microeinsteins $m^{-2}$ $sec^{-1}$ (PAR).

These initial data indicate that we will have to restrict our measurements to certain time periods and to days with sufficiently high light levels. Because of the number of sites and the distances between them, this will complicate the logistics of our sampling.

Figure 12. A histogram of August mean 1 S.E. light levels $(uE/m^2/sec$ PAR) associated with each stomatal resistance reading of leatherleaf leaves in five separate bogs (N=30).
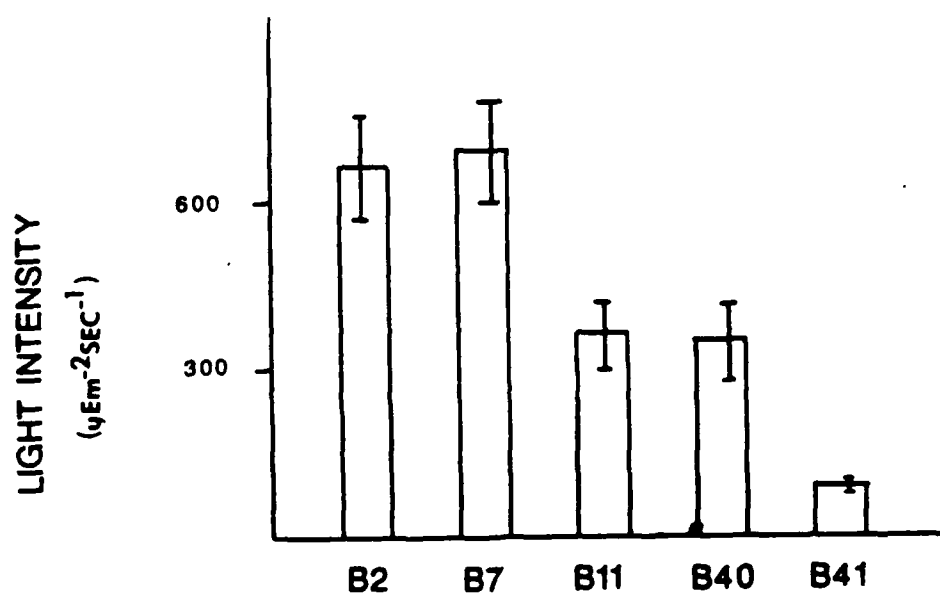
TABLE 18. THE RESULTS FROM AN ANALYSIS OF VARIANCE FOR
LEATHERLEAF STOMATAL RESISTANCE FROM FIVE BOGS NEAR THE WISCONSIN
TEST FACILITY IN AUGUST 1985.

| SOURCE | DF | SS | F |
|--------|----|------|-------|
| BOGS | 4 | 91.2 | 31.89 |
| ERROR | 145 | 103.7 | |
| TOTAL | 149 | 194.7 | |

| SOURCE | MEAN (SEC CM-1) | SE | CV |
|--------|-----------------|------|----|
| B2 (INT) | 1.8 | 0.08 | 24 |
| B7 (INT) | 2.1 | 0.13 | 33 |
| B11 (INT) | 2.4 | 0.19 | 46 |
| B40 (ANT) | 2.4 | 0.13 | 30 |
| B41 (BACK) | 4.0 | 0.20 | 28 |

significantly correlated, most values of r were less than 0.5. The ELF parameters were not found correlated with any of the decomposition samples.

# NITROGEN FIXATION

Biological nitrogen fixation is important in low nitrogen environments such as peat bogs which receive most of their nutrients from the atmosphere. Work by Damman (1978) and Hemond (1982) has shown that the amount of nitrogen incorporated in peat bogs is higher than that supplied by precipitation. This suggests that the balance is being recycled or being added from other sources. Bog systems contain free living and symbiotic microbes capable of nitrogen fixation. Symbiotic bacteria make their nitrogen as ammonia which is immediately available to their hosts. Free living cyanobacteria or heterotrophic bacteria release nitrogen upon cell lysis.

We had initially proposed to use speckled alder as our model system for studies of potential ELF effects on nitrogen fixation processes. Speckled alder is a shrub that forms a symbiotic relationship with a nitrogen fixing bacterium. Use of alder was discontinued because cuttings collected from the field rooted poorly. We had planned to use cuttings to grow uniform individuals that could be transplanted into our study sites. However, cuttings collected in the fall did not root even after a cold treatment. Cuttings collected in the spring broke bud and leafed out but we could induce root growth in less than 10%. With this low percentage of rooting we would have needed enormous numbers of cuttings to establish enough plants for field studies.

In 1985, we decided to concentrate on nitrogen fixation by

microorganisms associated with Sphagnum mosses and peat. We developed and field tested a chamber to be used for the acetylene reduction assay. This assay is based on the fact that the nitrogenase enzyme, which reduces atmospheric nitrogen to ammonia, also reduces acetylene to ethylene. Suitable plant material is incubated with acetylene; gas samples are then taken and analyzed on a gas chromatograph for the presence of acetylene. This is a sensitive assay which can detect quantities of ethylene to less than 10 -12 moles of ethylene per 200ul of injected acetylene (Hardy et al. 1968). The amount of ethylene produced can then be converted to the amount of nitrogen which could be reduced per unit area of live Sphagnum or peat.

The chambers we used have air tight lids fitted with serum stoppers for the introduction and removal of gases. A standard sized Sphagnum (green part of moss only) or subsurface peat core was placed in the container and acetylene was added to a final concentration of 10%. The samples were incubated approximately one hour in situ with their orientation preserved. The gas samples were stored in Vacutainers (evacuated blood collection tubes) until they could be analyzed.

Measured samples were withdrawn from the storage containers and analyzed on a gas chromatograph with appropriate column and standard conditions. Although ethylene was detected in incubated samples collected in a bog near Milwaukee,no ethylene was detected in our samples from the Clam Lake area. Chapman and Hemond (1982) report a decrease in ethylene production later in the season and on overcast days. It rained and was cool and

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overcast during the August sampling trip. They also note a loss of gas from Vacutainers stored longer than 7 days. Our samples could not analyzed until eight days after collection. If the amount of ethylene produced had been small it could have been lost before analysis.

Future work will involve monthly sampling during the growing season, longer incubations (2-3 hours) to generate higher ethylene concentrations, and quicker analysis of gas samples. In addition, larger assay containers may be used for subsurface peat samples which have been shown to have lower fixation rates than surface material (Schwintzer 1983).

# DECOMPOSITION

The results of four sets of decomposition samples from 1984 and 1985 are presented in this section. The study of cellulose decomposition was completed this year with samples that had been in place during three separate time periods: October 1983 to October 1984 (Set IV, 12 months), June 1984 to October 1984 (Set V, 4 months), and June 1984 to June 1985 (Set VI, 12 months). In 1985, we also began a decomposition experiment using senescent leaves of labrador tea (Ledum groenlandicum). The first set of samples was collected in October 1985 after having been placed in June 1985 (4 months).

## CELLULOSE DECOMPOSITION

The average percentage weight loss by the three samples is shown in Tables 19-21. Sets IV and VI (both 12 month incubations) are similar. As expected, when Set V (4 months) is compared with set VI (12 months), it is evident that greater than half of the decomposition of cellulose occurs during the summer months.

We assume that little weight loss occurs in the winter when temperatures are below zero and the samples are frozen in the upper peat strata or to the surface of the peat. Weight loss occurs primarily during ice-free periods, stimulated by biological activity and mediated by phenomena such as waterflow and freeze-thaw activity as well as environmental parameters. We used correlation analysis to determine whether any of the

Table 19. MEAN PERCENTAGE WEIGHT LOSS FOR CELLULOSE SQUARES (SET 4) INSERTED IN THE PEAT SUBSTRATE IN BOGS OF THE CLAM LAKE LAKE AREA AFTER TWELVE MONTHS INCUBATION (OCTOBER 1983 TO OCTOBER 1984).

| Bog | TYPE | MEAN | S.E. | N | C.V. |
|-----|------|------|------|-----|------|
| 101 | 1 | 37.29 | 1.78 | 40 | 30 |
| 102 | 1 | 22.28 | 1.13 | 47 | 35 |
| 21 | 2 | 24.23 | 1.38 | 50 | 40 |
| 22 | 2 | 16.90 | 1.03 | 50 | 43 |
| 40 | 2 | 29.88 | 1.08 | 50 | 26 |
| 2 | 3 | 28.04 | 2.16 | 40 | 49 |
| 7 | 3 | 38.04 | 1.62 | 50 | 30 |
| 11 | 3 | 18.41 | 2.24 | 50 | 86 |
| 20 | 4 | 18.25 | 1.23 | 50 | 48 |
| 41 | 4 | 24.59 | 1.18 | 45 | 32 |
| 19 | 4 | 40.13 | 2.32 | 50 | 41 |

Site Bog 19 was replaced in later samples.

TYPE: 1=Ground Site, 2=Antennae Site, 3=Intermediate Site, 4=Background       Site

C.V.= Standard deviation divided by the mean times 100

Table 20. MEAN PERCENTAGE WEIGHT LOSS FOR CELLULOSE SQUARES (SET 5) INSERTED IN THE PEAT SUBSTRATE IN BOGS OF THE CLAM LAKE LAKE AREA AFTER FOUR MONTHS INCUBATION (JUNE 1984 TO OCTOBER 1984).

| Bog | TYPE | MEAN | S.E. | N | C.V. |
|-----|------|-------|------|----|------|
| 101 | 1 | 18.26 | 0.76 | 47 | 28 |
| 102 | 1 | 12.12 | 1.23 | 48 | 70 |
| 21 | 2 | 14.00 | 1.60 | 44 | 75 |
| 22 | 2 | 9.88 | 1.02 | 48 | 71 |
| 40 | 2 | 17.85 | 0.99 | 48 | 39 |
| 2 | 3 | 17.70 | 1.90 | 48 | 72 |
| 7 | 3 | 36.10 | 3.00 | 47 | 57 |
| 11 | 3 | 17.80 | 1.60 | 48 | 64 |
| 20 | 4 | 9.24 | 0.92 | 48 | 69 |
| 41 | 4 | 21.2 | 2.00 | 36 | 56 |
| 50 | 4 | 17.50 | 2.10 | 32 | 67 |

TYPE: 1=Ground Site, 2=Antennae Site, 3=Intermediate Site, 4=Background Site

C.V.= Standard Deviation divided by the mean times 100.

Table 21. MEAN PERCENTAGE WEIGHT LOSS FOR CELLULOSE SQUARES (SET 6) INSERTED IN THE PEAT SUBSTRATE IN BOGS OF THE CLAM LAKE LAKE AREA AFTER TWELVE MONTHS INCUBATION (JUNE 1984 TO JUNE 1985).

| Bog | TYPE | MEAN | S.E. | N | C.V. |
|-----|------|-------|------|-----|------|
| 101 | 1 | 29.52 | 1.27 | 48 | 30 |
| 102 | 1 | 17.55 | 1.07 | 48 | 42 |
| 21 | 2 | 22.90 | 1.90 | 48 | 59 |
| 22 | 2 | 12.53 | 1.07 | 47 | 58 |
| 40 | 2 | 27.56 | 1.32 | 47 | 33 |
| 2 | 3 | 23.70 | 1.90 | 48 | 54 |
| 7 | 3 | 47.60 | 3.10 | 48 | 45 |
| 11 | 3 | 24.0 | 2.20 | 48 | 63 |
| 20 | 4 | 15.73 | 1.38 | 48 | 61 |
| 41 | 4 | 36.10 | 2.80 | 47 | 52 |
| 50 | 4 | 39.20 | 2.80 | 48 | 49 |

TYPE: 1=Ground Site, 2=Antennae Site, 3=Intermediate Site, 4=Background Site

C.V.= Standard Deviation divided by the mean times 100

environmental parameters or ELF parameters track the decomposition process and may affect it.

Pearson correlation coefficients were determined between Set V and VI and the various environmental and ELF parameters (Tables 22-23). The $p < 0.5$ criterion was used for indicating significant correlations. Even significant correlations are so low that a regression analysis of the data can explain little of the variance associated with the decomposition data (e.g. July redox potential, although significantly correlated with the data for Set V, explains only 36% of the variance in that data set). Nested analysis of variance models did not detect any significant differences among ELF categories (Tables 24-25).

LABRADOR TEA DECOMPOSITION

Labrador Tea leaves were collected from Bog 41 (BACKGROUND) in September 1984. Labrador Tea usually has 3 to 4 cohorts of leaves present on the plant during the summer. The leaves we collected were produced in 1983, and would have been the normal contribution to the litter in the fall of 1984. We collected senescent leaves that were still attatched to the plant stems; these leaves would have naturally fallen off within one or two weeks of our collection.

Subsamples of leaves were air dried, weighed (approximately 0.5 grams), and placed in 2mm mesh fiberglass bags with a numbered tag. The bags were randomly distributed into groups to go into each bog. In June 1985, groups of 4 bags were tied onto a

Table 22.    Pearson correlation coefficients (r) for 1984
             decomposition samples and 1984 environmental
             parameters.   DECOMP - 5 is a set of cellulose
             samples incubated June, 1984 - October, 1984.
             * indicates P < .05 in a two-tailed test. N = 528.

| Environmental Variable | DECOMP-5 | | Environmental Variable | DECOMP-5 | |
|---|---|---|---|---|---|
| JUNT   | -.011 |   | SEPZ   | .307  | * |
| JUNPH  | -.226 |   | SEPT   | .098  |   |
| JUNSPC | .292  | * | SEPPH  | -.347 | * |
| JUNCA  | -.330 | * | SEPSPC | .451  | * |
| JUNMG  | -.290 | * | SEPEH  | .109  |   |
| JUNK   | -.066 |   | SEPCA  | -.188 |   |
| JUNAB  | .028  |   | SEPMG  | -.246 | * |
| JUNOM  | -.015 |   | SEPAB  | .086  |   |
| JULZ   | .368  | * | SEPOM  | .002  |   |
| JULT   | -.025 |   | SEPSI  | .056  |   |
| JULPH  | -.425 | * | OCTZ   | .289  | * |
| JULSPC | .518  | * | OCTT   | .186  |   |
| JULEH  | .614  | * | OCTPH  | -.312 | * |
| JULCA  | -.205 |   | OCTSPC | .465  | * |
| JULMG  | -.215 |   | OCTEH  | -.116 |   |
| JULK   | -.085 |   | OCTCA  | -.213 |   |
| JULAB  | .024  |   | OCTMG  | -.253 | * |
| JULOM  | -.176 |   | OCTAB  | .057  |   |
| AGZ    | .302  | * | OCTOM  | .011  |   |
| AGT    | -.060 |   | OCTSI  | .109  |   |
| AGPH   | -.343 | * | AIR    | -.153 |   |
| AGSPC  | .436  | * | EARTH  | -.158 |   |
| AGEH   | .358  | * | MAG    | -.116 |   |
| AGCA   | -.132 |   |        |       |   |
| AGMG   | -.225 |   |        |       |   |
| AGK    | -.050 |   |        |       |   |
| AGAB   | .069  |   |        |       |   |
| AGOM   | .151  |   |        |       |   |

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Table 23.    Pearson correlation coefficients (r) for 1985
             decomposition samples and 1985 environmental
             parameters.   DECOMP-6 is a set of cellulose
             samples incubated June, 1984 - June, 1985.
             LABTEAl is a set of Labrador Tea leaves, incubated
             June, 1985 - October, 1985.   * indicates P < .05
             in a two-tailed test.   N = 528 for each set.

| Environmental Parameter | DECOMP-6 | | LABTEAl | |
|---|---|---|---|---|
| MAYT | -.184 | | -.215 | |
| MAYPH | -.298 | * | -.165 | |
| MAYSPC | .362 | * | .254 | * |
| MAYCA | -.223 | | -.221 | |
| MAYMG | -.408 | * | -.272 | * |
| MAYK | .162 | | -.058 | |
| MAYAB | .065 | | -.122 | |
| MAYZ | .216 | | .193 | |
| JUNT | -.050 | | -.120 | |
| JUNSPC | .420 | * | .269 | * |
| JUNCA | -.332 | * | -.283 | * |
| JUNMG | -.340 | * | -.303 | * |
| JUNK | -.094 | | -.047 | |
| JUNAB | .033 | | -.164 | |
| JUNZ | -.306 | * | -.209 | |
| JULT | .172 | | .038 | |
| JULPH | -.173 | | -.238 | |
| JULSPC | .488 | * | .276 | * |
| JULCA | -.381 | * | -.375 | * |
| JULMG | -.407 | * | -.347 | * |
| JULK | -.043 | | -.137 | |
| JULAB | .037 | | -.147 | |
| AUG | .112 | | .087 | |
| AUGT | -.184 | | -.183 | |
| AUGPH | -.347 | * | -.372 | * |
| AUGSPC | .526 | * | .332 | * |
| AUGCA | -.324 | * | -.322 | * |
| AUGMG | -.466 | * | -.220 | |
| AUGK | -.157 | | -.085 | |
| AUGAB | .021 | | -.133 | |
| SEPZ | -.132 | | -.184 | |
| SEPT | -.046 | | .063 | |
| SEPPH | -.369 | * | -.141 | |
| SEPSPC | .531 | * | .218 | |
| SEPCA | -.388 | * | -.412 | * |
| SEPMG | -.416 | * | -.325 | * |
| SEPK | -.073 | | .008 | |
| SEPAB | -.047 | | -.175 | |
| EARTH | -.237 | | -.309 | * |
| MAG | -.117 | | -.248 | * |

TABLE 24. RESULTS OF NESTED ANALYSIS OF VARIANCE FOR
DECOMPOSITION SETS 4 AND 5 COLLECTED IN 1984. SIGNIFICANCE OF THE
F STATISTIC FOR ELF LEVELS PRESENTED IN WHICH COMBINATIONS OF
ANTENNA,INTERMEDIATE, BACKGROUND, AND GROUND BOGS HAVE BEEN
EXCLUDED.

BOGS EXCLUDED          SIGNIFICANCE OF F

|     |     |    | SET 4 | N     | SET 5 | N     |
|-----|-----|----|-------|-------|-------|-------|
| 101 | 102 |    | .861  | (450) | .350  | (450) |
|     |     |    |       |       |       |       |
| 21  | 11  | 50 | .526  | (400) | .557  | (400) |
| 21  | 2   | 20 | .881  | (400) | .449  | (400) |
| 21  | 2   | 41 | .960  | (400) | .458  | (400) |
| 21  | 7   | 20 | .710  | (400) | .518  | (400) |
| 21  | 7   | 41 | .884  | (400) | .868  | (400) |
| 21  | 11  | 20 | .740  | (400) | .444  | (400) |
| 21  | 7   | 50 | .769  | (400) | .951  | (400) |
| 21  | 2   | 50 | .854  | (400) | .562  | (400) |
| 21  | 11  | 41 | .848  | (400) | .453  | (400) |
|     |     |    |       |       |       |       |
| 22  | 11  | 41 | .945  | (400) | .448  | (400) |
| 22  | 11  | 50 | .479  | (400) | .574  | (400) |
| 22  | 2   | 20 | .956  | (400) | .476  | (400) |
| 22  | 7   | 41 | .898  | (400) | .858  | (400) |
| 22  | 7   | 50 | .658  | (400) | .982  | (400) |
| 22  | 7   | 20 | .723  | (400) | .510  | (400) |
| 22  | 11  | 20 | .895  | (400) | .470  | (400) |
| 22  | 2   | 41 | .995  | (400) | .454  | (400) |
| 22  | 2   | 50 | .841  | (400) | .579  | (400) |
|     |     |    |       |       |       |       |
| 40  | 11  | 20 | .501  | (400) | .291  | (400) |
| 40  | 11  | 50 | .344  | (400) | .437  | (400) |
| 40  | 2   | 20 | .732  | (400) | .296  | (400) |
| 40  | 7   | 41 | .774  | (400) | .608  | (400) |
| 40  | 7   | 50 | .632  | (400) | .756  | (400) |
| 40  | 11  | 41 | .674  | (400) | .342  | (400) |
| 40  | 7   | 20 | .543  | (400) | .166  | (400) |
| 40  | 2   | 41 | .867  | (400) | .347  | (400) |
| 40  | 2   | 50 | .743  | (400) | .441  | (400) |

TABLE 25. RESULTS OF NESTED ANALYSIS OF VARIANCE FOR
DECOMPOSITION SETS 6 AND LABRADOR TEA COLLECTED IN 1985.
SIGNIFICANCE OF THE F STATISTIC FOR ELF LEVELS PRESENTED IN WHICH
COMBINATIONS OF ANTENNA,INTERMEDIATE, BACKGROUND, AND GROUND BOGS
HAVE BEEN EXCLUDED.

| BOGS EXCLUDED | | | SIGNIFICANCE OF F | | | |
|---|---|---|---|---|---|---|
| | | | SET 6 | N | LABRADOR TEA | |
| 101 | 102 | | .536 | (432) | .306 | (432) N |
| | | | | | | |
| 21 | 11 | 50 | .702 | (384) | .151 | (384) |
| 21 | 2 | 20 | .427 | (384) | .583 | (384) |
| 21 | 2 | 41 | .742 | (384) | .623 | (384) |
| 21 | 7 | 20 | .250 | (384) | .345 | (384) |
| 21 | 7 | 41 | .938 | (384) | .383 | (384) |
| 21 | 11 | 20 | .731 | (384) | .276 | (384) |
| 21 | 7 | 50 | .416 | (384) | .132 | (384) |
| 21 | 2 | 50 | .956 | (384) | .398 | (384) |
| 21 | 11 | 41 | .714 | (384) | .267 | (384) |
| | | | | | | |
| 22 | 11 | 41 | .811 | (384) | .478 | (384) |
| 22 | 11 | 50 | .768 | (384) | .300 | (384) |
| 22 | 2 | 20 | .488 | (384) | .765 | (384) |
| 22 | 7 | 41 | .988 | (384) | .619 | (384) |
| 22 | 7 | 50 | .996 | (384) | .259 | (384) |
| 22 | 7 | 20 | .134 | (384) | .542 | (384) |
| 22 | 11 | 20 | .474 | (384) | .473 | (384) |
| 22 | 2 | 41 | .822 | (384) | .814 | (384) |
| 22 | 2 | 50 | .781 | (384) | .568 | (384) |
| | | | | | | |
| 40 | 11 | 20 | .290 | (384) | .478 | (384) |
| 40 | 11 | 50 | .587 | (384) | .299 | (384) |
| 40 | 2 | 20 | .300 | (384) | .774 | (384) |
| 40 | 7 | 41 | .820 | (384) | .612 | (384) |
| 40 | 7 | 50 | .830 | (384) | .249 | (384) |
| 40 | 11 | 41 | .621 | (384) | .249 | (384) |
| 40 | 7 | 20 | .116 | (384) | .536 | (384) |
| 40 | 2 | 41 | .632 | (384) | .823 | (384) |
| 40 | 2 | 50 | .600 | (384) | .573 | (384) |

long piece of nylon line and four groups were placed in hollows

around each well. The bogs were placed flat on the bog surface

and the line for each group tethered to a fiberglass rod to

facilitate retrieval in the fall. It was felt that placing

samples onto the bog surface was a more natural placement for

leaves, as they normally fall from the plant and begin to compose

on the surface of the peat. Sphagnum moss in the hollows grew

over our sample bags during the summer so we felt the conditions

for decomposition were reasonably natural and homogenous. We

removed eight bags ( 2 groups of four) from each well site in

November 1985 after four months of incubation. Several hundred

additional bags were also placed in Bog 41 (BACKGROUND). Each

month 20 to 30 samples were collected from this site to give us

an indication of the normal pattern of decay over the course of

the summer and fall. The leaves were removed from all the

collected bags, dried, and reweighed to obtain percentage weight

loss.

Average weight loss within each bog is presented in Table

26. The coefficients of variation are relatively low for these

samples resembling the low values we found for mineral nutrients.

They are certainly lower than most values found for the cellulose

squares.

Nested analyses of variance models detected no significant

ELF category effects for this decomposition sample set (Table

25). Pearson correlation coefficients were calculated between

mean weight loss at each well site and the various environmental

and ELF parameters (Table 23). Although several pairings were

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Table 26. MEAN PERCENTAGE WEIGHT LOSS FOR LABRADOR TEA LEAVES
PLACED ON THE PEAT SUBSTRATE IN BOGS OF THE CLAM LAKE LAKE AREA
AFTER FOUR MONTHS INCUBATION (JUNE 1985 TO OCTOBER 1985).

| Bog | TYPE | MEAN | S.E. | N | C.V. |
|-----|------|-------|------|-----|------|
| 101 | 1 | 14.71 | 0.37 | 48 | 18 |
| 102 | 1 | 16.45 | 0.69 | 48 | 29 |
| 21 | 2 | 16.25 | 0.47 | 47 | 20 |
| 22 | 2 | 15.10 | 0.37 | 48 | 17 |
| 40 | 2 | 15.02 | 0.44 | 47 | 20 |
| 2 | 3 | 16.05 | 0.37 | 48 | 16 |
| 7 | 3 | 17.96 | 0.70 | 47 | 27 |
| 11 | 3 | 14.87 | 0.41 | 48 | 19 |
| 20 | 4 | 17.06 | 0.51 | 48 | 21 |
| 41 | 4 | 17.51 | 0.57 | 48 | 23 |
| 50 | 4 | 16.32 | 0.65 | 48 | 27 |

TYPE: 1=Ground Site, 2=Antennae Site, 3=Intermediate Site,
4=Background Site

C.V.= Standard Deviation divided by the mean times 100

significantly correlated, most values of r were less than 0.5. The ELF parameters were not found correlated with any of the decomposition samples.

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APPENDIX A

1984 WATER QUALITY DATA

APPENDIX A. CONTINUED
JUNE

| BOG | TYPE | W.T. (cm) | pH | K25 (uS/cm) | Ca++ (mg/1) | Mg++ (mg/1) | K+ (mg/1) | COLOR (Abs) |
|---|---|---|---|---|---|---|---|---|
| 2 | 3 | N/A | 3.41 (0.04) | 31.48 (1.38) | 1.42 (0.23) | 0.40 (0.05) | 0.31 (0.06) | 0.78 (0.09) |
| 7 | 3 | N/A | 3.16 (0.02) | 35.02 (1.61) | 1.12 (0.07) | 0.34 (0.02) | 0.58 (0.12) | 1.08 (0.08) |
| 11 | 3 | N/A | 3.63 (0.09) | 37.62 (0.91) | 1.20 (0.09) | 0.66 (0.04) | 0.56 (0.12) | 0.97 (0.09) |
| 20 | 4 | N/A | 3.28 (0.02) | 29.47 (0.35) | 1.38 (0.12) | 0.36 (0.01) | 0.67 (0.10) | 0.65 (0.03) |
| 41 | 4 | N/A | 3.18 (0.02) | 29.78 (0.82) | 0.77 (0.06) | 0.24 (0.01) | 0.50 (0.05) | 0.81 (0.03) |
| 50 | 4 | N/A | 3.36 (0.02) | 32.67 (1.78) | 0.79 (0.03) | 0.23 (0.01) | 0.49 (0.05) | 0.80 (0.06) |

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APPENDIX A. Water quality data for JUNE 1984. Values are means ± 1S.E.

| BOG | TYPE* | W.T.** (cm) | pH | K25*** (uS/cm) | Ca++ (mg/1) | Mg++ (mg/1) | K+ (mg/1) | COLOR (Abs) |
|-----|-------|-------------|-----|-----------------|-------------|-------------|-----------|-------------|
| 101 | 1 | N/A | 3.37 (0.02) | 30.35 (0.60) | 2.46 (0.06) | 0.76 (0.01) | 0.82 (0.18) | 1.31 (0.03) |
| 102 | 1 | N/A | 3.29 (0.05) | 31.23 (0.58) | 1.84 (0.12) | 0.59 (0.04) | 0.79 (0.10) | 1.15 (0.04) |
| 212 | 2 | N/A | 3.32 (0.03) | 32.22 (0.60) | 1.64 (0.10) | 0.48 (0.04) | 0.39 (0.08) | 1.09 (0.03) |
| 21 | 2 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 22 | 2 | N/A | 3.65 (0.03) | 29.10 (0.85) | 3.12 (0.41) | 0.77 (0.04) | 0.53 (0.10) | 1.30 (0.09) |
| 40 | 2 | N/A | 3.41 (0.05) | 30.97 (0.57) | 1.21 (0.05) | 0.43 (0.02) | 0.61 (0.11) | 0.98 (0.02) |

\* TYPE: 1=Ground Site, 2=Antenna Site, 3=Intermediate Site, 4=Background Site

\*\* W.T.=Depth from peat surface to water table

\*\*\* K25=Specific conductance corrected to 25 C

APPENDIX A. Water quality data for JULY 1984. Values are means $\pm$ 1S.E.

| BOG | TYPE* | W.T.** (cm) | pH | K25*** (uS/cm) | Ca++ (mg/l) | Mg++ (mg/l) | K+ (mg/l) | COLOR (Abs) |
|---|---|---|---|---|---|---|---|---|
| 101 | 1 | 6.17 (0.75) | 3.27 (0.02) | 32.30 (0.39) | 3.01 (0.10) | 0.87 (0.02) | 0.49 (0.09) | 1.25 (0.03) |
| 102 | 1 | 4.40 (0.74) | 3.41 (0.03) | 30.40 (0.70) | 1.98 (0.08) | 0.67 (0.04) | 0.54 (0.14) | 1.11 (0.02) |
| 212 | 2 | 3.33 (0.49) | 3.28 (0.05) | 31.70 (0.91) | 1.58 (0.07) | 0.53 (0.03) | 0.45 (0.11) | 1.04 (0.04) |
| 21 | 2 | 3.45 (0.72) | 3.46 (0.03) | 39.22 (0.81) | 1.40 (0.10) | 1.01 (0.53) | 0.53 (0.09) | 1.16 (0.08) |
| 22 | 2 | 6.57 (0.84) | 3.52 (0.06) | 29.30 (0.84) | 3.20 (0.29) | 0.87 (0.05) | 0.36 (0.13) | 1.30 (0.09) |
| 40 | 2 | 3.28 (0.42) | 3.16 (0.01) | 38.90 (0.64) | 1.40 (0.08) | 0.47 (0.03) | 0.54 (0.20) | 0.97 (0.01) |

\* TYPE: 1=Ground Site, 2=Antenna Site, 3=Intermediate Site, 4=Background Site

\*\* W.T.=Depth from peat surface to water table

\*\*\* K25=Specific conductance corrected to 25 C

APPENDIX A. CONTINUED

| JULY BOG | TYPE | W.T. (cm) | pH | K25 (uS/cm) | Ca++ (mg/l) | Mg++ (mg/l) | K+ (mg/l) | COLOR (Abs) |
|---|---|---|---|---|---|---|---|---|
| 2 | 3 | 4.25 (0.42) | 3.15 (0.02) | 39.60 (1.76) | 1.56 (0.27) | 0.41 (0.08) | 0.27 (0.09) | 0.82 (0.11) |
| 7 | 3 | 10.07 (1.20) | 3.08 (0.03) | 48.83 (2.02) | 1.37 (0.08) | 0.35 (0.02) | 0.40 (0.09) | 1.06 (0.06) |
| 11 | 3 | 10.72 (1.03) | 3.34 (0.06) | 37.73 (1.12) | 1.20 (0.08) | 0.34 (0.02) | 0.27 (0.06) | 1.01 (0.07) |
| 20 | 4 | 3.78 (0.34) | 3.13 (0.02) | 31.17 (1.28) | 1.21 (0.09) | 0.38 (0.02) | 0.42 (0.14) | 0.62 (0.02) |
| 41 | 4 | 9.95 (0.71) | 3.07 (0.02) | 34.57 (0.82) | 0.84 (0.07) | 0.26 (0.02) | 0.27 (0.04) | 0.78 (0.04) |
| 50 | 4 | 6.92 (0.76) | 3.12 (0.02) | 34.00 (1.98) | 0.81 (0.06) | 0.24 (0.01) | 0.36 (0.06) | 0.81 (0.07) |

APPENDIX A. Water quality data for AUGUST 1984. Values are means $\pm$ 1S.E.

| BOG | TYPE* | W.T.** (cm) | pH | K25*** (uS/cm) | Ca++ (mg/l) | Mg++ (mg/l) | K+ (mg/l) | COLOR (Abs) |
|-----|-------|-------------|-----|----------------|-------------|-------------|-----------|-------------|
| 101 | 1 | 5.62 (0.49) | 3.58 (0.02) | 32.97 (0.52) | 3.24 (0.08) | 0.98 (0.02) | 0.85 (0.13) | 1.34 (0.03) |
| 102 | 1 | 8.63 (0.91) | 3.42 (0.01) | 34.12 (0.90) | 2.63 (0.34) | 0.76 (0.03) | 0.83 (0.23) | 1.20 (0.05) |
| 212 | 2 | 10.53 (0.36) | 3.38 (0.03) | 33.23 (0.64) | 1.55 (0.07) | 0.55 (0.04) | 0.34 (0.08) | 1.13 (0.04) |
| 21 | 2 | 11.55 (1.03) | 3.33 (0.01) | 35.20 (0.76) | 1.47 (0.14) | 0.50 (0.05) | 0.33 (0.04) | 1.12 (0.09) |
| 22 | 2 | 13.42 (0.78) | 3.62 (0.04) | 28.47 (0.82) | 3.45 (0.30) | 0.97 (0.04) | 0.42 (0.12) | 1.37 (0.07) |
| 40 | 2 | 2.33 (0.46) | 3.44 (0.02) | 33.78 (0.55) | 1.67 (0.09) | 0.56 (0.04) | 0.99 (0.39) | 1.04 (0.01) |

\* TYPE: 1=Ground Site, 2=Antenna Site, 3=Intermediate Site, 4=Background Site

\*\* W.T.=Depth from peat surface to water table

\*\*\* K25=Specific conductance corrected to 25 C

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APPENDIX A. CONTINUED

| AUGUST BOG | TYPE | W.T. (cm) | pH | K25 (uS/cm) | Ca++ (mg/1) | Mg++ (mg/1) | K+ (mg/1) | COLOR (Abs) |
|---|---|---|---|---|---|---|---|---|
| 2 | 3 | 9.15 (0.53) | 3.39 (0.03) | 31.73 (1.71) | 1.92 (0.34) | 0.51 (0.09) | 0.23 (0.10) | 0.88 (0.12) |
| 7 | 3 | 17.17 (1.18) | 3.24 (0.01) | 41.46 (0.98) | 1.80 (0.23) | 0.43 (0.03) | 0.44 (0.15) | 1.22 (0.09) |
| 11 | 3 | 10.38 (1.11) | 3.27 (0.02) | 37.47 (0.82) | 1.41 (0.07) | 0.38 (0.01) | 0.26 (0.07) | 1.07 (0.06) |
| 20 | 4 | 5.97 (0.29) | 3.36 (0.02) | 28.93 (0.26) | 1.33 (0.08) | 0.39 (0.02) | 0.38 (0.13) | 0.67 (0.02) |
| 41 | 4 | 12.72 (0.70) | 3.29 (0.02) | 33.85 (0.76) | 1.01 (0.03) | 0.28 (0.01) | 0.31 (0.05) | 0.81 (0.02) |
| 50 | 4 | 14.30 (0.73) | 3.26 (0.01) | 33.17 (1.45) | 1.03 (0.06) | 0.25 (0.01) | 0.40 (0.11) | 0.84 (0.05) |

APPENDIX A. Water quality data for Sept. 1984. Values are means $\pm$ 1S.E.

| BOG | TYPE* | W.T.** (cm) | pH | K25*** (uS/cm) | Ca++ (mg/1) | Mg++ (mg/1) | K+ (mg/1) | COLOR (Abs) |
|-----|-------|-------------|-----|----------------|-------------|-------------|-----------|-------------|
| 101 | 1 | 0.17 (0.76) | 3.40 (0.01) | 29.55 (0.66) | 2.91 (0.07) | 0.69 (0.02) | N/A | 1.15 (0.03) |
| 102 | 1 | 2.43 (0.89) | 3.29 (0.02) | 32.88 (0.71) | 2.27 (0.11) | 0.60 (0.03) | N/A | 1.12 (0.03) |
| 212 | 2 | 3.20 (0.48) | 3.19 (0.003) | 34.12 (0.65) | 1.63 (0.10) | 0.52 (0.02) | N/A | 1.08 (0.03) |
| 21 | 2 | 2.75 (1.08) | 3.12 (0.01) | 38.07 (0.53) | 1.47 (0.10) | 0.45 (0.03) | N/A | 1.03 (0.07) |
| 22 | 2 | 4.08 (0.64) | 3.41 (0.03) | 31.43 (0.88) | 3.52 (0.22) | 0.85 (0.21) | N/A | 1.31 (0.05) |
| 40 | 2 | 1.20 (0.27) | 3.19 (0.02) | 33.92 (0.54) | 2.01 (0.08) | 0.52 (0.03) | N/A | 0.94 (0.06) |

\* TYPE: 1=Ground Site, 2=Antenna Site, 3=Intermediate Site, 4=Background Site

\*\* W.T.=Depth from peat surface to water table

\*\*\* K25=Specific conductance corrected to 25 C

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APPENDIX A. (continued)

SEPTEMBER

| BOG | TYPE | W.T. (cm) | pH | K25 (uS/cm) | Ca++ (mg/l) | Mg++ (mg/l) | K+ (mg/l) | COLOR (Abs) |
|-----|------|-----------|-----|-------------|-------------|-------------|-----------|-------------|
| 2 | 3 | 5.78 (0.51) | 3.20 (0.03) | 36.32 (1.05) | 1.86 (0.27) | 0.46 (0.06) | N/A | 0.89 (0.10) |
| 7 | 3 | 7.62 (1.06) | 3.08 (0.02) | 45.45 (2.47) | 2.02 (0.10) | 0.41 (0.03) | N/A | 1.19 (0.06) |
| 11 | 3 | 4.40 (1.40) | 3.10 (0.02) | 40.87 (1.48) | 1.51 (0.05) | 0.33 (0.02) | N/A | 1.04 (0.06) |
| 20 | 4 | 1.55 (0.43) | 3.23 (0.03) | 33.33 (0.72) | 1.74 (0.14) | 0.40 (0.02) | N/A | 0.69 (0.01) |
| 41 | 4 | 6.27 (0.44) | 3.13 (0.01) | 38.30 (0.40) | 1.50 (0.17) | 0.31 (0.01) | N/A | 0.81 (0.01) |
| 50 | 4 | 5.63 (0.88) | 3.16 (0.05) | 39.15 (1.08) | 1.46 (0.03) | 0.31 (0.01) | N/A | 0.84 (0.01) |

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APPENDIX A. Water quality data for October 1984. Values are means $\pm$ 1S.E.

| BOG | TYPE* | W.T.** (cm) | pH | K25*** (uS/cm) | Ca++ (mg/l) | Mg++ (mg/i) | K+ (mg/l) | COLOR (Abs) |
|---|---|---|---|---|---|---|---|---|
| 101 | 1 | -2.57 (0.70) | 3.39 (0.02) | 28.18 (0.43) | 2.45 (0.07) | 0.65 (0.02) | N/A | 0.90 (0.02) |
| 102 | 1 | -0.78 (0.73) | 3.39 (0.03) | 32.62 (1.37) | 2.14 (0.13) | 0.60 (0.02) | N/A | 0.97 (0.05) |
| 212 | 2 | 0.10 (0.49) | 3.21 (0.01) | 32.90 (1.17) | 1.43 (0.12) | 0.48 (0.04) | N/A | 0.91 (0.08) |
| 21 | 2 | 0.07 (0.80) | 3.16 (0.02) | 36.75 (0.68) | 1.19 (0.11) | 0.40 (0.02) | N/A | 0.89 (0.05) |
| 22 | 2 | 2.22 (0.76) | 3.43 (0.03) | 29.48 (0.59) | 3.52 (0.42) | 0.87 (0.03) | N/A | 1.27 (0.06) |
| 40 | 2 | -1.60 (0.39) | 3.21 (0.02) | 30.43 (0.85) | 1.78 (0.14) | 0.47 (0.03) | N/A | 0.79 (0.02) |

\* TYPE: 1=Ground Site, 2=Antenna Site, 3=Intermediate Site, 4=Background Site

\*\* W.T.=Depth from peat surface to water table

\*\*\* K25=Specific conductance corrected to 25 C

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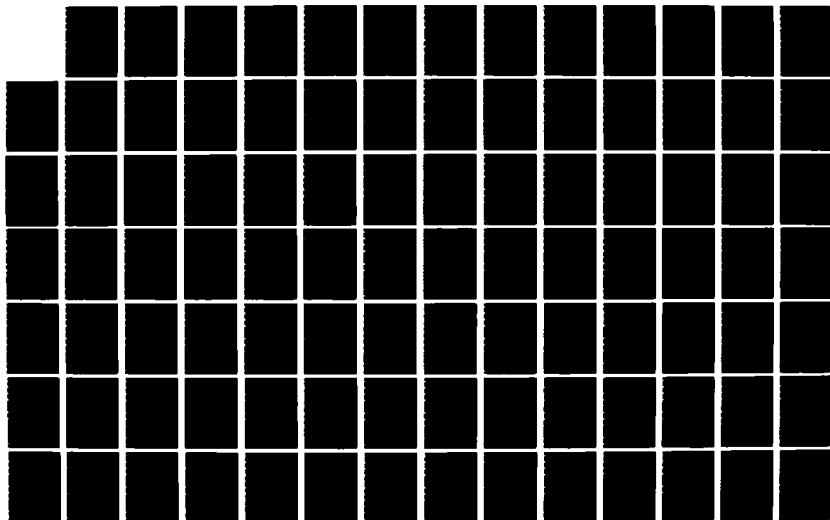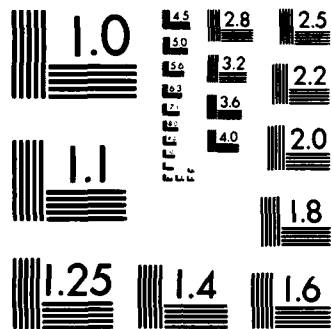
MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

APPENDIX A. (continued)

| OCTOBER BOG | TYPE | W.T. (cm) | pH | K25 (uS/cm) | Ca++ (mg/1) | Mg++ (mg/1) | K+ (mg/1) | COLOR (Abs) |
|---|---|---|---|---|---|---|---|---|
| 2 | 3 | -0.02 (0.60) | 3.20 (0.02) | 36.58 (2.05) | 1.90 (0.24) | 0.49 (0.05) | N/A | 0.81 (0.08) |
| 7 | 3 | 5.38 (1.35) | 3.11 (0.01) | 47.25 (2.37) | 1.47 (0.16) | 0.41 (0.02) | N/A | 1.07 (0.05) |
| 11 | 3 | 2.12 (1.02) | 3.25 (0.04) | 42.23 (1.00) | 1.63 (0.04) | 0.37 (0.02) | N/A | 0.98 (0.06) |
| 20 | 4 | -1.33 (o.77) | 3.18 (0.03) | 33.72 (0.62) | 1.27 (0.05) | 0.39 (0.01) | N/A | 0.63 (0.01) |
| 41 | 4 | 2.32 (1.50) | 3.15 (0.02) | 39.53 (1.22) | 1.15 (0.11) | 0.29 (0.01) | N/A | 0.76 (0.03) |
| 50 | 4 | 2.22 (0.74) | 3.12 (0.02) | 40.33 (1.28) | 1.01 (0.06) | 0.27 (0.01) | N/A | 0.84 (0.07) |

APPENDIX B

1985 WATER QUALITY DATA

APPENDIX B. Water quality data for 1985. Values are means $\pm$ 1S.E.

| MAY BOG | Temp C | W.T.** (cm) | pH | K25*** (uS/cm) | Ca++ (mg/l) | Mg++ (mg/l) | K+ (mg/l) | COLOR (Abs) |
|---|---|---|---|---|---|---|---|---|
| 101 | 11.13 | 0.3 | 3.84 | 33.0 | 2.0 | 0.56 | 0.16 | 0.84 |
|  | .016 | 0.15 | 0.07 | 0.54 | 0.05 | 0.01 | 0.02 | 0.01 |
| 102 | 10.17 | 1.3 | 3.8 | 36.7 | 1.5 | .45 | .20 | .72 |
|  | .016 | 0.41 | 0.08 | 0.73 | 0.07 | 0.02 | 0.04 | 0.02 |
| 21 | 9.47 | 1.6 | 3.57 | 46.11 | 1.1 | .30 | .42 | .75 |
|  | 0.74 | 0.29 | 0.04 | 0.71 | 0.08 | 0.02 | 0.13 | 0.05 |
| 22 | 10.97 | 4.1 | 4.01 | 36.43 | 2.4 | .60 | .40 | 1.02 |
|  | 0.34 | 0.62 | 0.05 | 1.38 | 0.43 | 0.06 | 0.08 | 0.07 |
| 40 | 11.12 | 2.2 | 3.42 | 33.96 | 1.2 | .31 | .21 | .59 |
|  | 0.29 | 0.46 | 0.06 | 2.64 | 0.05 | 0.02 | 0.05 | 0.01 |

**  W.T.=Depth from peat surface to water table

*** K25=Specific conductance corrected to 25 C

APPENDIX B (continued)

MAY

| BOG | T C | W.T. cm | pH | K25 (uS/cm) | Ca++ (mg/l) | Mg++ (mg/l) | K+ (mg/l) | COLOR (Abs) |
|---|---|---|---|---|---|---|---|---|
| 2 | 12.18 0.23 | 1.0 0.53 | 3.73 0.67 | 43.43 2.53 | 1.4 0.11 | .40 0.06 | .38 0.17 | .65 0.06 |
| 7 | 9.63 0.47 | 3.3 0.79 | 3.51 0.03 | 53.47 1.64 | 1.4 0.13 | .32 0.03 | .64 0.08 | .99 0.05 |
| 11 | 10.30 0.29 | 4.1 0.76 | 3.46 0.05 | 53.39 3.49 | 1.3 0.13 | .32 0.03 | .64 0.15 | .84 0.07 |
| 20 | 9.37 0.43 | 1.7 0.56 | 3.52 0.08 | 38.05 1.37 | 1.2 0.07 | .34 0.03 | .27 0.07 | .51 0.02 |
| 41 | 8.88 0.25 | 5.6 0.45 | 3.47 0.06 | 43.98 1.46 | 1.3 0.14 | .22 0.03 | .30 0.05 | .58 0.03 |
| 50 | 6.87 0.72 | 3.6 0.76 | 3.58 0.07 | 43.77 1.02 | 1.0 0.07 | .16 0.01 | .50 0.07 | .59 0.04 |

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APPENDIX B (continued)

JUNE

| BOG | Temp*<br>C | W.T.**<br>(cm) | pH | K25***<br>(uS/cm) | Ca++<br>(mg/l) | Mg++<br>(mg/l) | K+<br>(mg/l) | COLOR<br>(Abs) |
|-----|------------|----------------|------|-------------------|----------------|----------------|--------------|----------------|
| 101 | 16.3<br>0.68 | -0.3<br>0.14 | N/A<br>N/A | 32.2<br>0.94 | 2.2<br>0.11 | 0.55<br>0.02 | 0.10<br>0.03 | 0.82<br>0.03 |
| 102 | 15.3<br>0.32 | 0.2<br>0.21 | N/A<br>N/A | 38.9<br>1.16 | 1.8<br>0.09 | 0.49<br>0.02 | 0.14<br>0.04 | 0.76<br>0.03 |
| 21 | 14.1<br>0.42 | N/A<br>N/A | N/A<br>N/A | 47.6<br>1.04 | 0.90<br>0.12 | 0.30<br>0.04 | 0.18<br>0.03 | 0.75<br>0.08 |
| 22 | 14.7<br>0.18 | N/A<br>N/A | N/A<br>N/A | 38.3<br>0.77 | 2.8<br>0.25 | 0.68<br>0.04 | 0.08<br>0.03 | 1.07<br>0.06 |
| 40 | 13.7<br>0.23 | N/A<br>N/A | N/A<br>N/A | 35.7<br>0.93 | 1.3<br>0.09 | 0.34<br>0.02 | 0.05<br>0.01 | 0.64<br>0.02 |

** W.T.=Depth from peat surface to water table

*** K25=Specific conductance corrected to 25 C

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APPENDIX B (continued)

JUNE

| BOG | T (C) | W.T. cm | pH | K25 (uS/cm) | Ca++ (mg/l) | Mg++ (mg/l) | K+ (mg/l) | COLOR (Abs) |
|-----|-------|---------|-----|-------------|-------------|-------------|-----------|-------------|
| 2 | 15.5 0.28 | N/A N/A | N/A N/A | 42.8 1.51 | 1.4 0.18 | 0.53 0.18 | – – | 0.66 0.06 |
| 7 | 14.1 0.46 | 2.3 0.48 | N/A N/A | 57.1 1.53 | 1.3 0.07 | 0.31 0.02 | 0.27 0.12 | 0.95 0.06 |
| 11 | 15.6 0.27 | 1.9 0.82 | N/A N/A | 52.6 1.77 | 1.5 0.11 | 0.37 0.02 | 0.19 0.07 | 0.93 0.07 |
| 20 | 13.8 0.41 | -0.3 0.18 | N/A N/A | 37.2 0.40 | 1.4 0.08 | 0.34 0.01 | 0.08 0.02 | 0.56 0.02 |
| 41 | 13.9 0.52 | 1.8 0.54 | N/A N/A | 46.9 0.45 | 1.3 0.17 | 0.23 0.02 | 0.10 0.02 | 0.69 0.03 |
| 50 | 13.5 0.67 | 0.4 0.23 | N/A N/A | 45.4 2.32 | 1.1 0.03 | 0.22 0.01 | 0.22 0.06 | 0.71 0.06 |

APPENDIX B (continued)

JULY

| BOG | Temp* C | W.T.** (cm) | pH | K25*** (uS/cm) | Ca++ (mg/l) | Mg++ (mg/l) | K+ (mg/l) | COLOR (Abs) |
|-----|---------|-------------|------|----------------|-------------|-------------|-----------|-------------|
| 101 | 16.8 | N/A | 4.3 | 38.3 | 2.3 | 0.66 | 0.11 | 1.00 |
|     | 0.36 | N/A | 0.01 | 0.90 | 0.04 | 0.01 | 0.04 | 0.02 |
| 102 | 16.8 | N/A | 4.1 | 41.3 | 1.7 | 0.54 | 0.21 | 0.90 |
|     | 0.30 | N/A | 0.02 | 0.80 | 0.04 | 0.02 | 0.07 | 0.02 |
| 21  | 15.8 | N/A | 3.9 | 50.2 | 1.1 | 0.39 | 0.16 | 0.90 |
|     | 0.50 | N/A | 0.04 | 0.50 | 0.11 | 0.03 | 0.03 | 0.05 |
| 22  | 16.5 | N/A | 4.0 | 40.1 | 2.9 | 0.76 | 0.21 | 1.20 |
|     | 0.11 | N/A | 0.10 | 1.00 | 0.24 | 0.05 | 0.07 | 0.06 |
| 40  | 16.1 | N/A | 3.9 | 40.1 | 1.3 | 0.40 | 0.22 | 0.70 |
|     | 0.29 | N/A | 0.05 | 0.30 | 0.07 | 0.02 | 0.07 | 0.01 |

**   W.T.=Depth from peat surface to water table

***   K25=Specific conductance corrected to 25 C

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APPENDIX B (continued)

JULY

| BOG | T (C) | W.T. cm | pH | K25 (uS/cm) | Ca++ (mg/1) | Mg++ (mg/1) | K+ (mg/1) | COLOR (Abs) |
|---|---|---|---|---|---|---|---|---|
| 2 | 18.3 0.14 | N/A N/A | 3.9 0.01 | 47.5 2.70 | 1.6 0.24 | 0.42 0.06 | 0.09 0.02 | 0.70 0.09 |
| 7 | 17.9 0.18 | N/A N/A | 4.0 0.02 | 59.1 1.70 | 1.2 0.03 | 0.35 0.02 | 0.33 0.12 | 1.10 0.04 |
| 11 | 16.5 0.20 | N/A N/A | 3.8 0.02 | 52.6 2.00 | 1.2 0.08 | 0.32 0.02 | 0.38 0.22 | 0.90 0.06 |
| 20 | 15.0 0.30 | N/A N/A | 4.0 0.02 | 40.1 0.60 | 1.1 0.06 | 0.33 0.02 | 0.11 0.03 | 0.60 0.01 |
| 41 | 15.8 0.30 | N/A N/A | 3.8 0.03 | 48.8 0.60 | 0.80 0.04 | 0.23 0.01 | 0.12 0.03 | 070 0.02 |
| 50 | 15.0 0.54 | N/A N/A | 3.9 0.03 | 48.6 1.60 | 0.9 0.04 | 0.21 0.01 | 0.29 0.10 | 0.70 0.03 |

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APPENDIX B (continued)

AUGUST

| BOG | Temp* C | W.T.** (cm) | pH | K25*** (uS/cm) | Ca++ (mg/l) | Mg++ (mg/l) | K+ (mg/l) | COLOR (Abs) |
|-----|---------|-------------|-----|----------------|-------------|-------------|-----------|-------------|
| 101 | 14.7 | 0.5 | 4.1 | 37.2 | 2.4 | 0.32 | 0.15 | 0.96 |
|     | 0.30 | 0.29 | 0.02 | 1.19 | 0.05 | 0.01 | 0.04 | 0.02 |
| 102 | 15.0 | 1.7 | 3.8 | 42.0 | 1.8 | 0.27 | 0.40 | 0.93 |
|     | 0.23 | 0.30 | 0.06 | 0.63 | 0.11 | 0.01 | 0.16 | 0.02 |
| 21 | 14.0 | 0.50 | 3.9 | 47.0 | 1.1 | 0.38 | 0.13 | 0.93 |
|     | 0.27 | 0.66 | 0.05 | 1.81 | 0.11 | 0.02 | 0.04 | 0.04 |
| 22 | 14.9 | 2.3 | 4.1 | 39.0 | 3.0 | 0.73 | 0.43 | 1.18 |
|     | 0.09 | 0.41 | 0.03 | 0.49 | 0.21 | 0.04 | 0.31 | 0.05 |
| 40 | 15.0 | 0.4 | 3.9 | 38.5 | 1.3 | 0.39 | 0.18 | 0.74 |
|     | 0.17 | 0.43 | 0.04 | 0.73 | 0.09 | 0.02 | 0.04 | 0.03 |

\*\*   W.T.=Depth from peat surface to water table

\*\*\* K25=Specific conductance corrected to 25 C

APPENDIX B (continued)

AUGUST

| BOG | T (C) | W.T. cm | pH | K25 (uS/cm) | Ca++ (mg/l) | Mg++ (mg/l) | K+ (mg/l) | COLOR (Abs) |
|-----|-------|---------|-----|-------------|-------------|-------------|-----------|-------------|
| 2  | 15.8 0.28 | -0.5 0.19 | 3.8 0.02 | 43.4 1.56 | 1.5 0.25 | 0.20 0.03 | 0.08 0.02 | 0.75 0.09 |
| 7  | 14.2 0.27 | -0.2 0.53 | 3.8 .0.02 | 57.1 1.38 | 1.3 0.05 | 0.19 0.01 | 0.35 0.10 | 1.12 0.04 |
| 11 | 15.1 0.07 | 2.5 0.74 | 3.8 0.05 | 50.6 1.88 | 1.2 0.09 | 0.16 0.01 | 0.46 0.32 | 0.95 0.07 |
| 20 | 13.5 0.02 | 1.3 0.61 | 4.0 0.02 | 40.0 0.47 | 1.3 0.04 | 0.38 0.01 | 0.11 0.04 | 0.62 0.01 |
| 41 | 13.8 0.19 | 4.9 1.00 | 3.7 0.04 | 48.8 0.39 | 1.0 0.01 | 0.26 0.01 | 0.09 0.02 | 0.74 0.02 |
| 50 | 13.4 0.36 | 4.2 0.56 | 3.8 0.03 | 50.4 1.25 | 1.0 0.07 | 0.26 0.01 | 0.15 0.06 | 0.77 0.03 |

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APPENDIX B (CONTINUED)

SEPTEMBER

| BOG | Temp* C | W.T.** (cm) | pH | K25*** (uS/cm) | Ca++ (mg/l) | Mg++ (mg/l) | K+ (mg/l) | COLOR (Abs) |
|-----|---------|-------------|-----|----------------|-------------|-------------|-----------|-------------|
| 101 | 13.4 | 1.2 | 4.2 | 43.6 | 2.3 | 0.69 | 0.11 | 0.89 |
|     | 0.25 | 0.37 | 0.01 | 1.27 | 0.05 | 0.02 | 0.02 | 0.02 |
| 102 | 13.5 | 2.5 | 4.1 | 40.7 | 1.9 | 0.60 | 0.51 | 0.90 |
|     | 0.12 | 0.43 | 0.0? | 0.79 | 0.08 | 0.02 | 0.17 | 0.03 |
| 21  | 11.4 | 0.40 | 3.8 | 51.2 | 1.2 | 0.43 | 0.17 | 0.92 |
|     | 0.11 | 0.68 | 0.04 | 0.89 | 0.14 | 0.03 | 0.06 | 0.05 |
| 22  | 12.4 | 4.2 | 4.2 | 40.3 | 3.0 | 0.85 | 0.13 | 1.19 |
|     | 0.15 | 0.58 | 0.03 | 0.69 | 0.27 | 0.06 | 0.06 | 0.07 |
| 40  | 11.8 | 1.4 | 3.8 | 41.7 | 1.5 | 0.46 | 0.24 | 0.74 |
|     | 0.08 | 0.66 | 0.06 | 0.64 | 0.06 | 0.02 | 0.06 | 0.02 |

** W.T.=Depth from peat surface to water table

*** K25=Specific conductance corrected to 25 C

APPENDIX B (continued)

SEPTEMBER

| BOG | T (C) | W.T. cm | pH | K25 (uS/cm) | Ca++ (mg/l) | Mg++ (mg/l) | K+ (mg/l) | COLOR (Abs) |
|-----|-------|---------|-----|-------------|-------------|-------------|-----------|-------------|
| 2   | 12.6  | -0.40   | 3.9 | 46.0        | 1.5         | 0.44        | 0.07      | 0.74        |
|     | 0.27  | 0.17    | 0.02| 2.68        | 0.34        | 0.07        | 0.01      | 0.10        |
| 7   | 12.0  | -0.40   | 3.8 | 58.3        | 1.2         | 0.39        | 0.41      | 1.06        |
|     | 0.10  | 0.64    | 0.02| 1.63        | 0.07        | 0.02        | 0.14      | 0.04        |
| 11  | 12.6  | 4.3     | 3.7 | 52.3        | 1.3         | 0.34        | 0.27      | 0.98        |
|     | 0.07  | 0.75    | 0.02| 1.90        | 0.11        | 0.01        | 0.17      | 0.06        |
| 20  | 12.6  | 1.4     | 3.9 | 41.2        | 1.2         | 0.40        | 0.25      | 0.62        |
|     | 0.19  | 0.26    | 0.02| 0.83        | 0.06        | 0.01        | 0.08      | 0.01        |
| 41  | 13.7  | 4.1     | 3.9 | 48.7        | 1.0         | 0.28        | 0.20      | 0.73        |
|     | 0.20  | 1.00    | 0.02| 0.67        | 0.06        | 0.01        | 0.05      | 0.02        |
| 50  | 12.4  | 2.8     | 3.8 | 51.2        | 1.0         | 0.27        | 0.21      | 0.74        |
|     | 0.15  | 0.63    | 0.02| 0.85        | 0.06        | 0.02        | 0.09      | 0.02        |

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APPENDIX C

NBS CERTIFIED STANDARDS VERSUS LABORATORY DERIVED VALUES

APPENDIX C. A COMPARISON OF CERTIFIED NBS CATION CONCENTRATIONS (MEAN ± 1 S.D.) AND VALUES OBTAINED WITH NBS STANDARD PLANT MATERIAL DIGESTED IN A HYDROGEN PEROXIDE - SULFURIC ACID MIXTURE.

CONCENTRATION (PERCENT DRY WEIGHT)

|            | NBS        | UWM        |
|------------|------------|------------|
| CA (N=15)  | .41±.02    | .41±.02    |
| MG (N=15)  | .58±.03    | .56±.001   |

APPENDIX D

LOCATION OF ELF WETLAND STUDY SITES IN WISCONSIN

Appendix D.  Map showing the location of bog study sites (GROUND = 101, 102;  ANTENNA = 21,22,40;  INTERMEDIATE = 2,7,11; AND BACKGROUND = 19,20,41,50)  along the ELF 76 Hz electromagnetic gradient produced by the Wisconsin Test Facility.
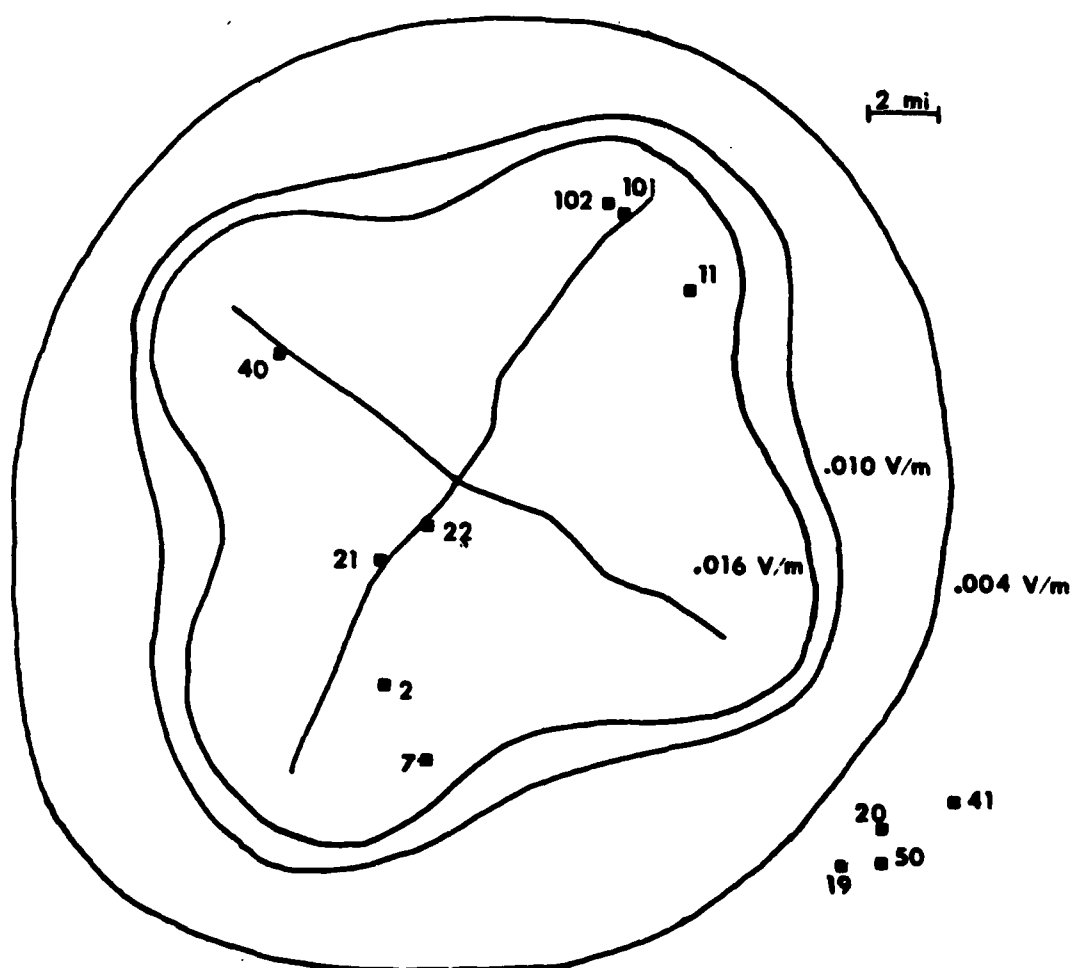
APPENDIX D2. SITE LOCATIONS AND DESCRIPTIONS OF ELF WETLAND SITES IN WISCONSIN

| Site Name | Type | County | Location |
|---|---|---|---|
| 2 | Intermediate | Ashland | T41N R4W, SW1/4 Sec 19 |
| 7 | Intermediate | Ashland | T41N R4W, SW1/4 Sec 33 |
| 11 | Intermediate | Ashland | T43N R4W, SE1/4 Sec 36 |
| 19 | Control | Sawyer | T40N R3W, NW1/4 Sec 15 |
| 20 | Control | Sawyer | T40N R3W, NE1/4 Sec 10 |
| 21 | Antennae | Sawyer | T41N R5W, SE1/4 Sec 01 |
| 22 | Antennae | Ashland | T42N R4W, SW1/4 Sec 31 |
| 40 | Antennae | Sawyer | T42N R5W, NW1/4 Sec 17 |
| 41 | Control | Sawyer | T40N R3W, SE1/4 Sec 02 |
| 50 | Control | Sawyer | T40N R3W, SE1/4 Sec 10 |
| 10T1 | Ground | Ashland | T43N R4W, SE1/4 Sec 22 |
| 10T2 | Ground | Ashland | T43N R4W, SE1/4 Sec 22 |

APPENDIX E
COEFFICIENTS OF VARIABILITY FOR 1984 FOLIAR SAMPLES

APPENDIX E1. Within bog nutrient concentration variability (C.V.= Coefficient of Variability) for June 1984 leatherleaf foliar samples.

| Bog# | K | Ca | Mg |
|------|------|------|------|
| 101 | 15.0 | 31.0 | 16.7 |
| 102 | 14.0 | 22.0 | 11.5 |
| 21 | 11.4 | 18.5 | 15.7 |
| 22 | 10.9 | 20.2 | 5.6 |
| 40 | 18.0 | 30.4 | 18.4 |
| 2 | 13.8 | 21.8 | 14.4 |
| 7 | 14.5 | 26.3 | 16.1 |
| 11 | 14.9 | 20.3 | 16.6 |
| 20 | 14.7 | 16.6 | 10.4 |
| 41 | 16.7 | 16.9 | 9.6 |
| 50 | 10.7 | 17.9 | 11.0 |

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APPENDIX E2. Within bog nutrient concentration variability (C.V.=Coefficient of variation) for July 1984 leatherleaf foliar samples.

| Bog # | K | Ca | Mg |
|---|---|---|---|
| 101 | 21.3 | 25.5 | 13.8 |
| 102 | 24.9 | 17.4 | 9.6 |
| 21 | 13.0 | 16.8 | 9.8 |
| 22 | 12.1 | 18.3 | 16.1 |
| 40 | 15.6 | 20.9 | 26.6 |
| 2 | 16.8 | 19.0 | 14.4 |
| 7 | 18.0 | 22.0 | 14.8 |
| 11 | 17.3 | 22.5 | 16.3 |
| 20 | 16.5 | 15.6 | 14.4 |
| 41 | 13.8 | 20.4 | 13.5 |
| 50 | 11.0 | 15.5 | 14.3 |

APPENDIX E3. Within bog nutrient concentration variability
(C.V.=Coefficient of Variability) for September 1984 Leatherleaf
samples.

| Bog# | K | Ca | Mg |
|------|------|------|------|
| 101 | 13.3 | 31.0 | 16.2 |
| 102 | 15.4 | 26.9 | 21.2 |
| 21 | 14.4 | 20.7 | 16.0 |
| 22 | 14.4 | 22.6 | 13.8 |
| 40 | 15.8 | 20.8 | 18.7 |
| 2 | 13.0 | 14.4 | 15.5 |
| 7 | 15.1 | 18.1 | 17.5 |
| 11 | 9.6 | 15.9 | 14.7 |
| 20 | 11.4 | 19.8 | 18.9 |
| 41 | 10.2 | 18.5 | 17.1 |
| 50 | 23.3 | 14.8 | 17.4 |

APPENDIX E4. Within bog nutrient concentration variability
(C.V.=Coefficient of Variability) for September 1984 Black Spruce
foliar samples.

| Bog# | K | Ca | Mg |
|------|------|------|------|
| 101 | 18.3 | 25.5 | 17.2 |
| 102 | 13.7 | 25.3 | 11.7 |
| 21 | 1.0 | 19.9 | 13.4 |
| 22 | 15.6 | 21.9 | 14.0 |
| 40 | 14.2 | 26.4 | 19.6 |
| 2 | 11.6 | 20.3 | 11.0 |
| 7 | 13.2 | 34.3 | 17.1 |
| 11 | 12.4 | 28.3 | 16.2 |
| 20 | 14.3 | 25.7 | 18.7 |
| 41 | 16.1 | 26.3 | 11.7 |
| 50 | 12.9 | 29.7 | 25.3 |

ELF COMMUNICATIONS SYSTEM ECOLOGICAL MONITORING PROGRAM:

BIRD SPECIES AND COMMUNITIES

ANNUAL REPORT: 1985

SUBCONTRACT NUMBER: E06549-84-011

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JoAnn M. Hanowski
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Jim Loukes
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# ABSTRACT

This investigation was designed to assess the effects of the extremely low frequency (ELF) antenna system on breeding bird species and communities at the existing antenna system near Clam Lake, Wisconsin and the pre-operational antenna system near Republic, Michigan. The 1985 season represented the first year that breeding data were collected (fall migration data were collected in 1984). Our objectives for 1985 were to: (1) select new or modify existing transects so that all electromagnetic field requirements were met; (2) evaluate our sampling methods and sample size requirements for the breeding season; and (3) address specific questions on whether there were differences in bird species and populations between control and treatment study areas.

We successfully addressed all objectives for 1985. Forty-one of 160 transect segments were replaced in early spring of 1985 and now they all meet the electromagnetic field requirements. Each transect was censused once in June and several transects were censused twice to analyze observer and daily variation. These data were used to determine the adequacy of the sample size, the number of breeding censuses required, and the differences between control and treatment transects in each state.

We chose (1) those species with a mean density > one individual observed/500 m transect segment in each state, (2) total number of species, and (3) total number of individuals to test for differences between control and treatment transects with one-way analysis of variance. We selected all other species that were present on at least five control or five treatment transect segments and tested for differences in frequencies of observations of a species with a G-test. Paired t-tests were used to assess daily and observer variation for those transect segments censused on two different days.

Eighty-one species and 2896 individuals were observed on all transects in Wisconsin. The Ovenbird and Red-eyed Vireo were the most common species on both control and treatment transects where they occurred in densities of > 4 individuals/500 m transect. More species, individuals, Chestnut-sided Warblers, Chipping Sparrows, and American Robins were observed on treatment as compared with the control transects ($P < 0.05$). In contrast, more Yellow-bellied Flycatchers and Winter Wrens were sighted on control transects ($P < 0.05$).

Eighty-one species and 2956 individuals were observed on all control and treatment transects in Michigan and like in Wisconsin, the Ovenbird and Red-eyed Vireo were the most common species present ( > 3.5 individuals/500 m transect). More individuals, Chestnut-sided Warblers, Mourning Warblers, White-throated Sparrows, Yellow-bellied Flycatchers, and Golden-crowned Kinglets were observed on treatment as compared with control transects ($P < 0.05$). The control transects had more Rose-breasted Grosbeaks and Winter Wrens than the treatment transects ($P < 0.05$).

We documented daily variation in censuses in Wisconsin by having the same observer census 8 transect segments on two different days. In these tests, the mean value of the two censuses was different from either day one or day two ($P < 0.05$) for 3 of 22 comparisons. In general, more species and individuals were observed on the first as compared with the second census and 38% of the species were recorded on both days. In Michigan, we assessed observer and daily variation by having one observer census the same eight transect segments that the other observer censused on a previous day. Here nine of 24 paired comparisons between the mean of the two censuses were different from day one or day two. We used the coefficient of variation and its relationship to the percent differences detectable

between two means to address whether two censuses increased our ability to detect smaller differences between two means. In Wisconsin, two censuses indicated that on average we would be able to detect a 3% smaller difference between means but data in Michigan indicated that one census would allow us to detect a 5% smaller difference between two means. Based on these data, we will census each transect once during the breeding season.

Our observed and a priori predicted means and variances for number of species and number of individuals observed on a 500 m transect segment were slightly different, but the percent differences detectable between two means were almost equal (mean = 7.5% observed versus 7% predicted). Densities of common species were lower than what we predicted and in general the percent differences detectable were higher than predicted (mean= 30.5% observed versus 16% predicted). However, the data analyses indicated that we could detect the differences between two means that we calculated with the observed variance and mean and most of these differences were within our initial goal of wanting to detect a difference of one individual between control and treatment transects.

A possible improvement to the analyses is to use a paired plot design. Michigan transects will be paired based on similarities in bird species composition because the antenna has not operated in that state. However, we cannot pair the Wisconsin transects in this manner because we cannot be certain that the antenna has not already altered the bird populations in the area. Therefore, we will measure habitat characteristics of the transect segments in Wisconsin to match control and treatment transects on the basis of the similarity of habitat characteristics. This task will be completed in 1986 and 1987.

We will also use our existing transects and methodology to examine the

## INTRODUCTION

Effects of extremely low frequency (ELF) electromagnetic fields on most aspects of a bird species life history are poorly understood (National Academy of Sciences 1977; Lee et al. 1979). Birds use the earth's magnetic fields to aid in their navigation during migration (Emlen 1975) and magnetic fields produced by the ELF communications system may affect their navigation abilities. Some investigations have reported that orientation of ring-billed gull chicks (Southern 1972, 1975) and migrating birds (Larkin and Sutherland 1977) were disrupted by the ELF antenna operating in Wisconsin. However, Williams and Williams (1976) found no evidence of attraction or repulsion of migrating birds in relation to the antenna during any mode of operation. Behavioral and physiological effects of domestic birds exposed to extremely low frequencies have been studied in the laboratory (Krueger et al. 1972; Durfee et al. 1976) and environmental studies of a native species [Tree Swallow (Tachycineta bicolor)] are currently underway at the ELF site in Michigan (Beaver et al. 1985).

In contrast to studies that have focused on assessing individuals of one or a few species, several investigators have studied the effects of ELF transmission lines on bird population parameters. These include: (1) the combined effect of habitat changes and electromagnetic fields (Anderson et al. 1975; Anderson 1979; Dawson and Gates 1979; Meyers and Provost 1979; Stapleton and Kiviat 1979; Bell 1980; Bramble et al. 1984; Niemi and Hanowski 1984); (2) the right-of-way (ROW) edge (Chasko and Gates 1982; Kroodsma 1982); (3) collision with lines (Beaulaurier et al. 1982); and (4) audible noise generated by the transmission lines (Lee and Griffith 1978). However, we are unaware of any bird investigations that have attempted to separate effects of electromagnetic fields from effects due to habitat

changes along the ROW on bird species and populations.

This investigation was designed to isolate effects of electromagnetic fields produced by ELF antenna systems on bird species and communities in Wisconsin and Michigan. In this report we summarize our major research activities for 1985. Our objectives for this time period were to: (1) select new or modify existing transects so that all electromagnetic field requirements were met; (2) evaluate our sampling methods and sample size requirements for the breeding season; and (3) address our specific questions of interest. These questions were: are there differences in (a) bird species richness; (b) relative community density; (c) relative density of an individual bird species; or (d) relative frequency of birds between treatment transects (those adjacent to the ELF antenna system) and control transects (those away from the influence of the ELF electromagnetic fields)? Pre-impact data were collected in Michigan during 1985 (the ROW was cut but the antenna was not operating) and this provides baseline information on inherent similarities and differences between control and treatment transects. These data will be compared to post-impact data to determine effects of electromagnetic fields on bird species and communities in Michigan and will be used in conjunction with post-impact data gathered in Wisconsin to infer effects of electromagnetic fields in that state.

## STUDY AREAS

Our experimental design for this investigation required a total of 40 control and 40 treatment experimental units. Because we were originally interested in assessing effects of the antenna in Michigan and Wisconsin independently, the total sample size required was 160. The next step was to design a transect that would allow us to efficiently census all experimental units. To accomplish this task, we specified the following

conditions: (1) all transect segments would be censused in the time period from one half hour before sunrise to four hours after sunrise; (2) 30 minutes were necessary to census each transect segment; and (3) effects of electromagnetic fields must be separated from effects of the ROW. The transect designed was 4350 m in length and consisted of eight 500 m transect segments and a 50 m buffer between each segment. The 50 m buffer was included to insure independence of the 500 m segments. The total time needed to census the entire transect is 4 hours and 35 minutes where 30 minutes is spent in each 500 m transect segment and 5 minutes is used to travel the 50 m between each 500 m transect segment. Treatment transects were positioned parallel and 125 m from the antenna corridor. With this design, we do not census the area within 25 m of the ROW and the ROW itself. This controls for "edge effect" (e.g., more species and idividuals) of the ROW (Chasko and Gates 1982). The placement of the treatment transects is a compromise to control for edge effect but also to maintain close proximity to the antenna to assure that the required electro-magnetic field ratios between control and treatment transects are met. Ideally one would like to have each 500 m transect segment randomly selected from throughout the study region. However, with this design much time would be lost in travelling from one transect segment to the next. By randomly selecting the location of the total transect (4350 m) and using the 50 m buffer, we achieve an efficient scheme and a reasonable compromise with statistical rigor (Eberhardt 1978; Anderson et al. 1979). In this report a "transect" is the sum of 8 - 500 m segments and the 50 m buffers and each 500 m segment is identified as a "transect segment" or "experimental unit" (Figure 1).

The starting locations for 10 control and 10 treatment transects were randomly selected in both Wisconsin and Michigan with methods described
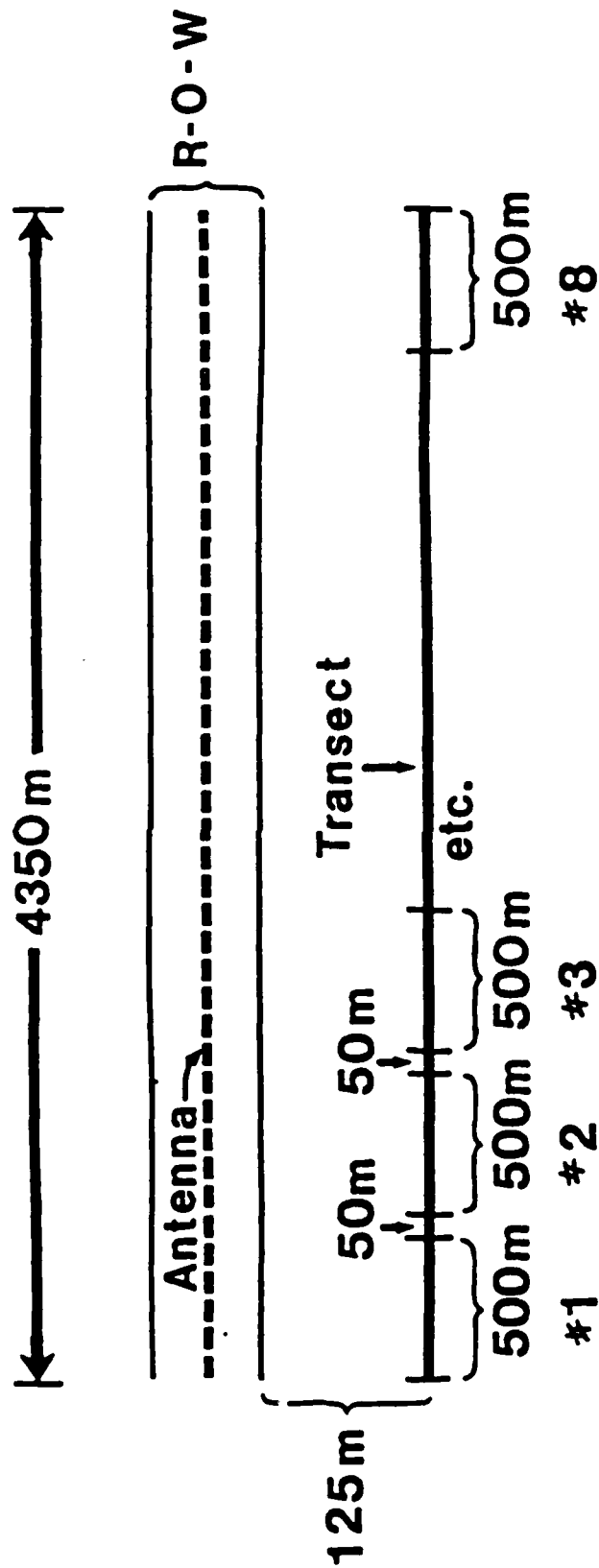
Figure 1. Schematic of a treatment transect layout.

previously (Niemi and Hanowski 1985). The transects were established (measured and flagged) in July and August 1984 and the electromagnetic fields at each study site were measured by IIT Research Institute (IITRI) personnel in late August and early September 1984 (see Brosh et al. 1985). Electromagnetic fields were measured at the start and end points of each transect but were not completed for each transect segment because these sites were not readily accessible (e.g., most are 1-4 km from a road). Here we assumed that the start and end point measurements should provide a suitable approximation for the transect segments between those end points.

Our experimental design for this investigation is a comparison of 40 control and 40 treatment transect segments in each state. The statistical analyses for the population data is analysis of variance and this design requires that all control and treatment transects fall within the required electromagnetic ratios. However, the original measurements indicated that several paired control and treatment transects did not meet these criteria (see Appendix A). For example, because all transects start at a road where 60 Hz powerlines are commonly located, several transects had high 60 Hz fields at the starting points. This situation was easily remedied by moving the starting points away from powerlines. This was done for three transects in Wisconsin (Woodtick Lake, Little Clam Lake, and Mineral Lake) and for two transects in Michigan (Arnold and Carney Lake). In addition, one transect in Wisconsin (Moose Lake) and three in Michigan (Birch Lake, Ralph North, and Ralph South) were replaced. These transects either had high 60 Hz at both ends (Moose Lake and Birch Lake) or had lower 60 Hz and higher 76 Hz ratios than what were acceptable (Ralph North and Ralph South). Starting points for new transects to replace the unacceptable transects were randomly selected using methods previously described (Niemi

and Hanowski 1985). The electromagnetic fields at each site were measured by IITRI personnel to determine whether they fell within the required ratios. The new transects were measured with a 12.5 m rope and compass and flagged during the spring of 1985. In summary, about one fourth (41) of all transect segments were replaced. All transects now satisfy the electromagnetic criteria and will be used for the remainder of the monitoring period.

Because of the transect changes and modifications required to satisfy the electromagnetic ratios between control and treatment transects, two transects are different in length than the original design (4350 m total length or 8 - 500 m segments separated by 50 m buffers). One transect in Wisconsin is 500 m shorter (Woodtick Lake) and one 500 m longer (Little Clam Lake) than the original design. This was done because electromagnetic fields were not suitable to add an additional 500 m transect segment to the Woodtick Lake transect. The first 500 m of the Little Clam Lake transect is censused on the same day as the 7 Woodtick Lake transect segments. These transects are adjacent to each other and we adjusted our census times so that all control and treatment transect segments were censused simultaneously and each observer still censused 8 transect segments/day. In addition, two 500 m transect segments of one treatment transect in Michigan (Flat Rock Creek) were considerably changed by logging activities (clearcut). These two 500 m transect segments were placed on the opposite side of the ROW where logging had not been completed and again we adjusted our census times to account for the time delay to reach that transect segment starting point.

Because many flag markers along the transects were lost due to natural weathering and vandalism, we walked each transect prior to censusing to insure that each censuser could locate his/her way during the census.

Transect names are provided in Table 1 and locations shown in Figures 2 and 3.

## METHODS

Bird censuses. Our original design was to census each transect segment twice during the breeding season. However, because of the previously mentioned changes in the transects and because all unchanged transects had to be walked, monetary restrictions made it necessary to alter this design. All transect segments (160 total) were censused once and sixteen control and treatment transect segments were censused twice in each state. This was done to document daily and observer variation between censuses. Daily variation of census data were assessed for eight control and eight treatment transect segments in Wisconsin. Here one observer censused the same eight transect segments on two different days. In Michigan, a combination of daily and observer variability were assessed on eight control and eight treatm transect segments. Here each observer censused the same eight transect segments that the other observer had censused on a previous date. The rationale for conducting two censuses this year was to determine whether two censuses would reduce the variation in the data and ultimately allow us to detect smaller differences between means.

We used the line transect method to census all transects (Emlen 1971, 1977; Järvinen and Väisänen 1975). Census data were gathered during early morning hours (0445-0920 CDST) on days when wind speed was < 10 km/hr and with no or only slight precipitation. Control and treatment transect segments were censused simultaneously by two observers to eliminate differences that could occur by censusing at different time periods. Censuses of control and treatment transects were randomly assigned to each of two observers with the restriction that each observer censused the same

Table 1.  Summary of Wisconsin and Michigan transect locations.

| Number and Name | Township | Range | Sections |
|---|---|---|---|
| **WISCONSIN** | | | |
| C1  Spillerberg Lake | 43N | 3W | 23,26,35 |
| C2  Mineral Lake | 44N | 4W | 15,16,17,18 |
| C3  Rock Lake | 42N<br>43N | 6W<br>6W | 6<br>19,30,31 |
| C4  Blaisdell Lake | 40N<br>40N | 4W<br>3W | 13,14,22,23<br>18 |
| C5  Brunette River | 40N | 3W | 16,21,28 |
| T1  Woodtick Lake | 43N | 4W | 22,23,27,28,33 |
| T2  Little Clam Lake | 42N | 4W | 5,8,17 |
| T3  Christy Lake | 42N | 5W | 7,8,15,16,17 |
| T4  Black Lake | 41N | 5W | 24,25,36 |
| T5  Moose River | 42N<br>42N | 3W<br>4W | 31<br>35,36 |
| **MICHIGAN** | | | |
| C1  Carney Lake | 41N | 29W | 33,34,35,36 |
| C2  Skunk Creek | 42N<br>42N | 28W<br>27W | 14,23,24<br>19,30 |
| C3  Arnold | 43N | 25W | 31,32,33,34 |
| C4  Lost Lake | 41N | 29W | 21,26,27,28,35 |
| C5  Bob's Creek | 44N | 26W | 13,23,24,26 |
| T1  Heart Lake | 45N<br>46N | 28W<br>29W | 7,18<br>1 |
| T2  Flat Rock Creek | 44N<br>45N | 28W<br>28W | 6<br>19,30,31 |
| T3  Schwartz Creek | 45N<br>45N | 28W<br>29W | 31<br>26,27,35,36 |
| T4  Turner Road | 43N<br>44N | 29W<br>29W | 1,11,12<br>36 |
| T5  Leeman's Road | 43N | 29W | 14,23,26,35 |
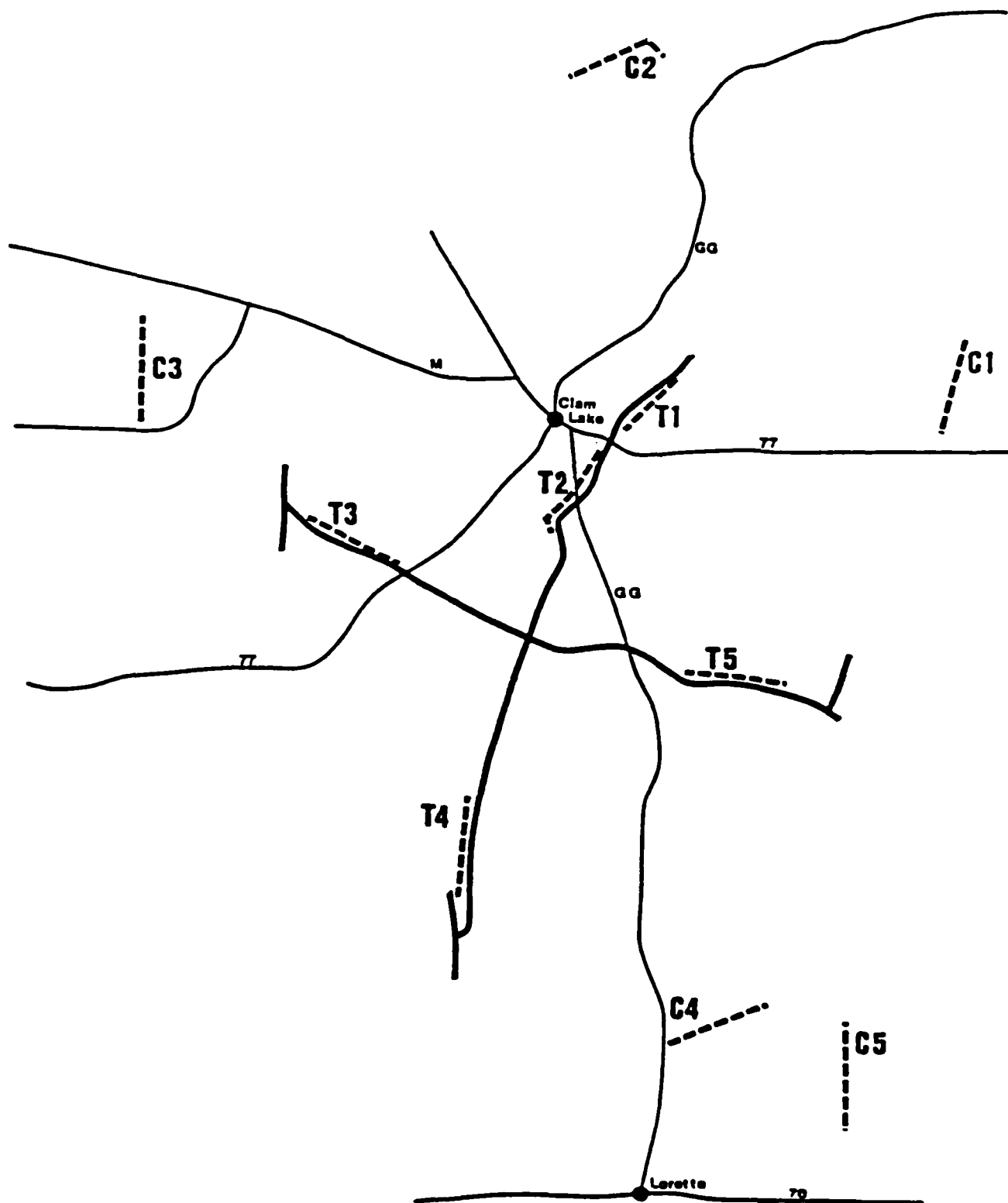
Figure 2.  Location of Wisconsin antenna and study transects.
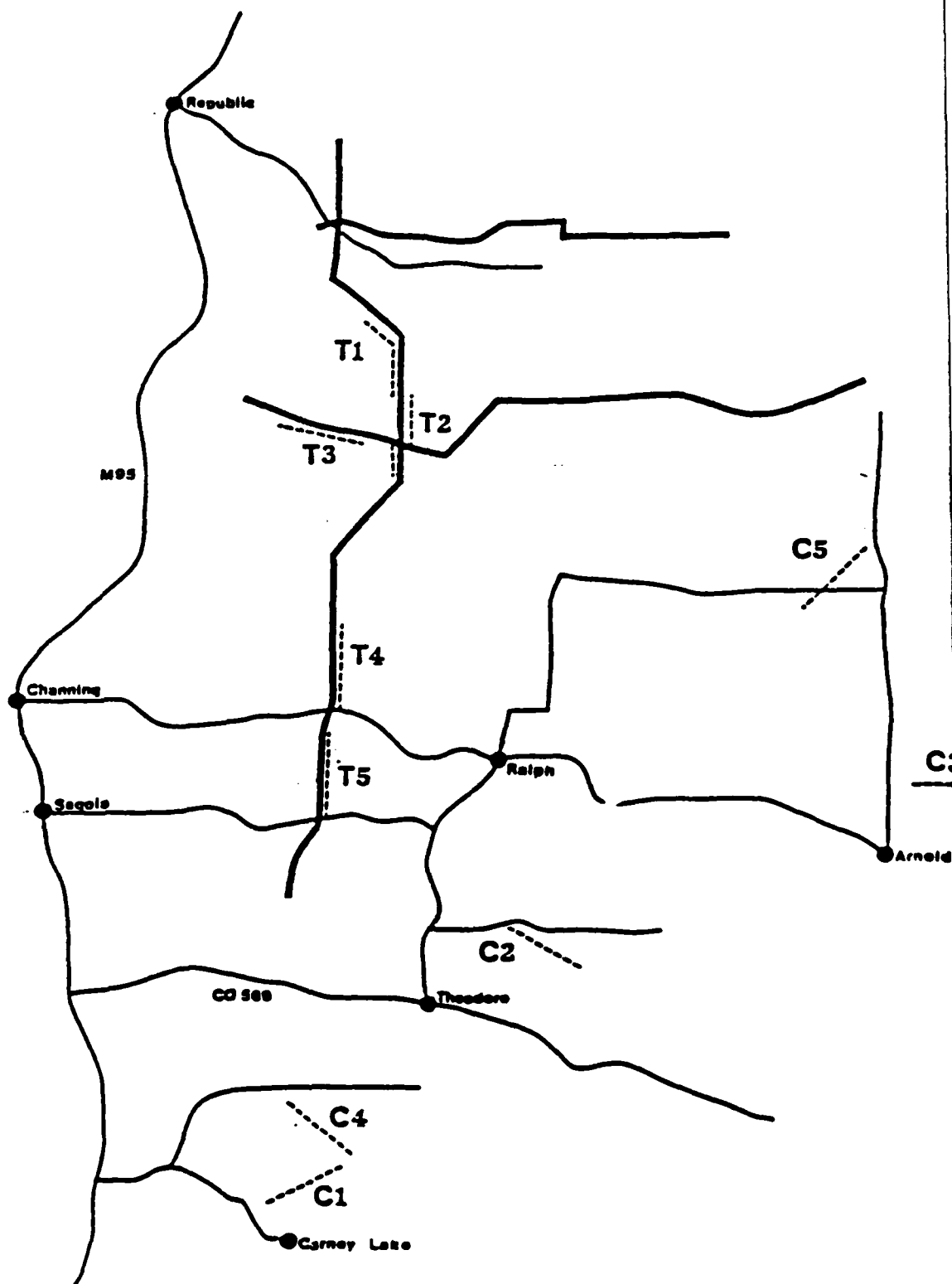
Figure 3. Location of Michigan antenna and study transects.

total number of control (80) and treatment (80) transect segments. This was done to control for potential differences in observers.

A total of eight transect segments were censused by each observer daily. Each observer walked the designated transect segment at a rate of 16.7 m/min and recorded the following information for each bird observed: (1) species; (2) sex when possible; (3) behavior (e.g., singing or calling); (4) estimated perpendicular distance from the transect in meters; (4) relative position to transect (e.g., right or left side); and (5) distance along the transect in meters from the start.

Data organization. All data were transferred from field sheets to a computer file. Individual birds flying over the area (e.g., above the canopy) were not included in the data file. The following parameters were recorded for each bird observation: (1) plot number - 1 to 160: (2) year and census number (1 or 2 for those transect segments censused twice): (3) perpendicular distance from transect segment in meters: (4) distance along the transect segment in meters, and (5) species, using a standardized American Ornithologists' Union numeric code (Klimkiewicz and Robbins 1978).

Data synthesis. All data were tabulated with the Statistical Package for the Social Sciences [SPSS (Nie et al. 1981)] using subprograms CROSSTABS and CONDESCRIPTIVE to provide species lists and number of observations of each species for each transect segment. Another file was then created that included: (1) transect number; (2) total number of species; (3) total number of individuals; and (4) number of individuals for each species present on the transect segment. This file included observations of birds up to 100 m from the transect.

Data transformations. We examined the data with respect to the assumptions

of normality and homoscedasticity of variance prior to statistical analyses (Sokal and Rohlf 1981). For example, skewness and kurtosis were calculated with SPSS subprogram CONDESCRIPTIVE to examine the normality of each variable and Bartlett's test for homogeneity of variances was calculated for each variable using SPSS subprogram ONEWAY. Several variance-stabilizing transformations (e.g., square root and logarithmic) were calulated for variables that did not meet these assumptions. We used logarithmic (natural) transformations in the final analyses because they were consistently best for reducing skewness, kurtosis, and the heterogeneity of variances.

Analyses of treatment effect. We chose (1) those species with a density > one/500 m transect segment in each state, (2) total number of species, and (3) total number of individuals to test for differences between control and treatment transects (SPSS ONEWAY). We selected all other species that were present on at least five control or five treatment transect segments in each state and tested for differences in a species presence with a G-test (Sokal and Ronlf 1981).

Analyses of daily and observer variation. We used a paired t-test (SPSS T-TEST) to assess daily variation in bird activity for data gathered on the same eight transect segments by the same observer on two different dates in Wisconsin. Here we compared data gathered on each date with the mean number of observations from both dates. We also assessed a combination of daily and observer variation on eight control and eight treatment transect segments in Michigan. Here 8 transect segments were censused by different observers on two separate days. All paired t-tests were computed for the same bird population parameters that we used in the one-way ANOVA. We also counted the number of species that were observed on date one only, on date

two only, and on both dates. We then computed the coefficient of variation (CV) for each bird parameter for each date and the mean from the two dates and determined the relationship between CV and the percent difference detectable between means.

We used the number of individuals observed up to 100 m from the transect in all data analyses instead of attempting to calculate a density value. Relative density could be calculated with a variety of formulae (Burnham et al. 1981; Emlen 1971, 1977; Järvinen and Väisänen 1975) but we have found from a previous study (Hanowski and Niemi in prep.) that there was a higher correlation (r > 0.70) between the number of observations and the density estimate from territorial mapping than any one formula (r < 0.67). We used territorial mapping as a standard for comparison because it is generally accepted as the most reliable density estimate for bird populations (see Tianen and Bastien 1983). A disadvantage to using a density formula such as LINETRAN (Burnham et al. 1981) is the number of observations required to obtain a reliable density estimate. For example, at least 30 observations/species are recommended to calculate densities with the Fourier series estimator. This is prohibitive in this study because we do not observe this many individuals of one species on a 500 m transect. To obtain the specified sample, our transects would have to be about five times longer (about 2500 m) than they are now. This design is not feasible because of the large sample size (number of transects) needed to detect the desired difference between control and treatment transects. It may be possible to use this technique (LINETRAN) at a later date if we pool data among years or among different experimental units.

Another advantage of our method of using the total number of observations is that we eliminate the potential variability between

observers to estimate distance (Svennson 1977). Here we only assume that the ability to detect individuals is similar between observers and therefore between control and treatment sites because each observer censuses the same number of control and treatment transect segments.

## RESULTS

Wisconsin bird populations. Eighty-one species and 2896 individuals were observed on all transect segments in Wisconsin. Sixty-six species (mean = 13) and 1348 individuals (mean = 33.7) were sighted on the control transect segments and 76 species (mean = 15) and 1548 individuals (mean = 38.7) were counted on treatment transect segments (Table 2). The Ovenbird and Red-eyed Vireo were the most common species on both control and treatment transect segments (mean > 4 individuals/transect segment). The significant differences between control and treatment transects are summarized as follows. More species and individuals (P < 0.05) were observed on treatment than control transect segments (Table 3). From a species perspective, more Chestnut-sided Warblers (P < 0.05) were observed on treatment transect segments as compared with control transect segments (mean = 1.98 and 0.98) but almost twice as many Yellow-bellied Flycatchers were observed on the control transect segments (mean = 0.63 and 0.34). Results of the G-tests (Table 4) indicated that the Winter Wren occurred more often on control than on treatment (15 and 6) transect segments (P < 0.05). The Chipping Sparrow and American Robin occurred more frequently (P < 0.05) on treatment (12 and 23 transect segments respectively) than on the control transect segments (4 and 5 transect segments respectively).

Daily variation in census data. We tested whether the mean number of observations for eleven bird population parameters were different from the numbers observed on two different census days. Paired t-tests indicated

Table 2. Total number of individuals observed for each species on control and treatment transects in Wisconsin and Michigan in June of 1985.

| Species | Wisconsin | | Michigan | |
| --- | --- | --- | --- | --- |
| | Control | Treatment | Control | Treatment |
| American Bittern Botaurus lentiginosus | 0 | 1 | 0 | 0 |
| Great Blue Heron Ardea herodias | 1 | 1 | 0 | 0 |
| Wood Duck Aix sponsa | 3 | 0 | 0 | 0 |
| Sharp-shinned Hawk Accipiter striatus | 0 | 0 | 1 | 1 |
| Northern Goshawk Accipiter gentilis | 0 | 0 | 0 | 1 |
| Broad-winged Hawk Buteo platypterus | 1 | 1 | 0 | 3 |
| Red-tailed Hawk Buteo jamaicensis | 0 | 0 | 1 | 0 |
| Ruffed Grouse Bonasa umbellus | 13 | 2 | 2 | 7 |
| Common Snipe Gallinago gallinago | 0 | 3 | 0 | 0 |
| American Woodcock Scolopax minor | 0 | 0 | 4 | 0 |
| Black-billed Cuckoo Coccyzus erythropthalmus | 1 | 2 | 0 | 1 |
| Barred Owl Strix varia | 0 | 0 | 3 | 0 |
| Whip-poor-will Caprimulgus ridgwayi | 0 | 0 | 1 | 0 |
| Ruby-throated Hummingbird Archilochus colubris | 0 | 1 | 2 | 0 |
| Yellow-bellied Sapsucker Sphyrapicus varius | 3 | 0 | 13 | 7 |
| Downy Woodpecker Picoides pubescens | 4 | 2 | 4 | 7 |
| Hairy Woodpecker Picoides villosus | 5 | 2 | 5 | 4 |
| Black-backed Woodpecker Picoides arcticus | 1 | 0 | 1 | 1 |

Table 2. Continued.

| Species | Wisconsin | | Michigan | |
|---|---|---|---|---|
| | Control | Treatment | Control | Treatment |
| Northern Flicker<br>_Colaptes auratus_ | 6 | 2 | 8 | 8 |
| Pileated Woodpecker<br>_Drvocopus pileatus_ | 5 | 1 | 4 | 5 |
| Olive-sided Flycatcher<br>_Contopus borealis_ | 3 | 1 | 0 | 1 |
| Eastern Wood-Peewee<br>_Contopus virens_ | 11 | 16 | 8 | 18 |
| Yellow-bellied Flycatcher<br>_Empidonax flaviventris_ | 62 | 23 | 6 | 44 |
| Alder Flycatcher<br>_Empidonax alnorum_ | 8 | 25 | 4 | 2 |
| Least Flycatcher<br>_Empidonax minimus_ | 64 | 34 | 48 | 34 |
| Great Crested Flycatcher<br>_Mylarchus crinitus_ | 38 | 16 | 19 | 11 |
| Eastern Kingbird<br>_Tvrannus tyrannus_ | 2 | 1 | 2 | 0 |
| Gray Jay<br>_Perisoreus canadensis_ | 0 | 2 | 0 | 3 |
| Blue Jay<br>_Cvanocitta cristata_ | 22 | 30 | 32 | 21 |
| American Crow<br>_Corvus brachvrhvnchos_ | 0 | 9 | 1 | 4 |
| Northern Raven<br>_Corvus corax_ | 4 | 3 | 4 | 4 |
| Black-capped Chickadee<br>_Parus atricapillus_ | 20 | 29 | 44 | 40 |
| Boreal Chickadee<br>_Parus hudsonicus_ | 0 | 2 | 1 | 2 |
| Red-breasted Nuthatch<br>_Sitta canadensis_ | 13 | 21 | 22 | 28 |
| White-breasted Nuthatch<br>_Sitta carolinensis_ | 3 | 1 | 9 | 7 |
| House Wren<br>_Troglodvtes aedon_ | 0 | 2 | 1 | 0 |
| Winter Wren<br>_Troglodvtes troglodvtes_ | 32 | 8 | 23 | 8 |
| Sedge Wren<br>_Cistothorus platensis_ | 0 | 11 | 4 | 3 |

Table 2. Continued.

| Species | Wisconsin | | Michigan | |
|---|---|---|---|---|
| | Control | Treatment | Control | Treatment |
| Golden-crowned Kinglet *Regulus satrapa* | 0 | 7 | 3 | 26 |
| Ruby-crowned Kinglet *Regulus calendula* | 0 | 2 | 2 | 1 |
| Veery *Catharus fuscescens* | 13 | 4 | 18 | 15 |
| Swainson's Thrush *Catharus ustulatus* | 6 | 0 | 0 | 0 |
| Hermit Thrush *Catharus guttatus* | 30 | 33 | 46 | 39 |
| American Robin *Turdus migratorius* | 10 | 38 | 21 | 41 |
| Gray Catbird *Dumetella carolinensis* | 0 | 0 | 4 | 7 |
| Brown Thrasher *Taxostoma rufum* | 1 | 1 | 0 | 2 |
| Cedar Waxwing *Bombycilla cedrorum* | 1 | 6 | 11 | 6 |
| Solitary Vireo *Vireo solitarius* | 7 | 12 | 8 | 6 |
| Yellow-throated Vireo *Vireo flavifrons* | 0 | 0 | 1 | 1 |
| Philadelphia Vireo *Vireo philadelphicus* | 0 | 2 | 0 | 0 |
| Red-eyed Vireo *Vireo olivaceus* | 178 | 185 | 144 | 185 |
| Golden-winged Warbler *Vermivora chrysoptera* | 7 | 6 | 3 | 5 |
| Nashville Warbler *Vermivora ruficapilla* | 125 | 173 | 96 | 228 |
| Northern Parula *Parula americana* | 21 | 12 | 9 | 1 |
| Yellow Warbler *Dendroica petechia* | 1 | 9 | 4 | 0 |
| Chestnut-sided Warbler *Dendroica pensylvanica* | 39 | 79 | 58 | 164 |
| Magnolia Warbler *Dendroica magnolia* | 6 | 14 | 1 | 4 |
| Cape May Warbler *Dendroica tigrina* | 16 | 15 | 4 | 4 |

Table 2. Continued.

| Species | Wisconsin | | Michigan | |
|---|---|---|---|---|
| | Control | Treatment | Control | Treatment |
| Black-throated Blue Warbler<br>*Dendroica caerulescens* | 3 | 1 | 0 | 1 |
| Yellow-rumped Warbler<br>*Dendroica coronata* | 7 | 19 | 3 | 19 |
| Black-throated Green Warbler<br>*Dendroica virens* | 121 | 99 | 102 | 70 |
| Blackburnian Warbler<br>*Dendroica fusca* | 8 | 6 | 7 | 3 |
| Pine Warbler<br>*Dendroica pinus* | 0 | 3 | 1 | 1 |
| Palm Warbler<br>*Dendroica palmarum* | 2 | 6 | 0 | 0 |
| Black-and-white Warbler<br>*Mniotilta varia* | 35 | 33 | 43 | 14 |
| American Redstart<br>*Setophaga ruticilla* | 2 | 5 | 2 | 2 |
| Ovenbird<br>*Seiurus aurocapillus* | 239 | 277 | 241 | 260 |
| Northern Waterthrush<br>*Seiurus noveboracensis* | 3 | 1 | 9 | 0 |
| Connecticut Warbler<br>*Oporornis agilis* | 4 | 8 | 0 | 1 |
| Mourning Warbler<br>*Oporornis philadelphia* | 28 | 29 | 19 | 63 |
| Common Yellowthroat<br>*Geothlypis trichas* | 22 | 44 | 22 | 14 |
| Canada Warbler<br>*Wilsonia canadensis* | 9 | 2 | 6 | 11 |
| Scarlet Tanager<br>*Piranga olivacea* | 5 | 4 | 5 | 8 |
| Rose-breasted Grosbeak<br>*Pheucticus ludovicianus* | 14 | 16 | 52 | 30 |
| Indigo Bunting<br>*Passerina cyanea* | 0 | 3 | 7 | 1 |
| Rufous-sided Towhee<br>*Pipilo erythrophthalmus* | 0 | 0 | 0 | 3 |
| Chipping Sparrow<br>*Spizella passerina* | 5 | 19 | 4 | 18 |
| Savannah Sparrow<br>*Passerculus sandwichensis* | 1 | 0 | 0 | 0 |

Table 2. Continued.

| Species | Wisconsin | | Michigan | |
|---|---|---|---|---|
| | Control | Treatment | Control | Treatment |
| Song Sparrow<br>_Melospiza melodia_ | 5 | 12 | 19 | 4 |
| Lincoln's Sparrow<br>_Melospiza lincolnii_ | 0 | 6 | 0 | 0 |
| Swamp Sparrow<br>_Melospiza georgiana_ | 1 | 13 | 8 | 6 |
| White-throated Sparrow<br>_Zonotrichia albicollis_ | 35 | 51 | 34 | 77 |
| Dark-eyed Junco<br>_Junco hyemalis_ | 1 | 1 | 1 | 1 |
| Red-winged Blackbird<br>_Agelaius phoeniceus_ | 1 | 5 | 15 | 0 |
| Common Grackle<br>_Quiscalus quiscula_ | 0 | 0 | 1 | 0 |
| Brown-headed Cowbird<br>_Molothrus ater_ | 1 | 2 | 5 | 1 |
| Northern Oriole<br>_Icterus galbula_ | 0 | 0 | 1 | 3 |
| Purple Finch<br>_Carpodacus purpureus_ | 4 | 3 | 7 | 5 |
| Red Crossbill<br>_Loxia curvirostra_ | 3 | 10 | 0 | 0 |
| Pine Siskin<br>_Carduelis pinus_ | 0 | 5 | 0 | 0 |
| American Goldfinch<br>_Carduelis tristis_ | 2 | 3 | 1 | 2 |
| Evening Grosbeak<br>_Coccothraustes vespertinus_ | 1 | 12 | 2 | 1 |
| Total Species | 66 | 76 | 72 | 70 |
| Total Individuals | 1348 | 1548 | 1327 | 1629 |

Table 3. Mean observations in a 500 m transect and significance of one-way ANOVA between control and treatment transects for 9 bird species and two community parameters in Wisconsin.

| Parameter | Control | | Treatment |
|---|---|---|---|
| Yellow-bellied Flycatcher[1] | 1.65 | * | 0.58 |
| Least Flycatcher[1] | 1.60 | | 0.85 |
| Red-eyed Vireo | 4.45 | | 4.63 |
| Nashville Warbler | 3.13 | | 4.33 |
| Chestnut-sided Warbler | 0.98 | * | 1.98 |
| Black-throated Green Warbler | 3.03 | | 2.48 |
| Ovenbird | 5.98 | | 6.93 |
| Common Yellowthroat[1] | 0.55 | | 1.10 |
| White-throated Sparrow | 0.88 | | 1.28 |
| Species | 13.03 | * | 15.00 |
| Individuals | 33.75 | ** | 38.73 |

[1] Log transformed before analyses

* P < 0.05

** P < 0.01

Table 4.  Percent and absolute number of total transect segments in parenthesis where each species was observed and significance of a G-test between control and treatment transects in Wisconsin (n = 40).

| Parameter | Control | | Treatment |
|---|---|---|---|
| Eastern Wood-Peewee | 20 (8) | | 20 (8) |
| Alder Flycatcher | 10 (4) | | 23 (9) |
| Great-crested Flycatcher | 43 (17) | | 55 (22) |
| Blue Jay | 38 (15) | | 50 (20) |
| Red-breasted Nuthatch | 30 (12) | | 35 (14) |
| Black-capped Chickadee | 38 (15) | | 48 (19) |
| Winter Wren | 38 (15) | * | 15 (6) |
| Hermit Thrush | 48 (19) | | 58 (23) |
| American Robin | 13 (5) | * | 58 (23) |
| Solitary Vireo | 13 (5) | | 18 (7) |
| Northern Parula | 30 (12) | | 25 (10) |
| Magnolia Warbler | 15 (6) | | 20 (8) |
| Blackburnian Warbler | 20 (8) | | 13 (5) |
| Black-and-White Warbler | 53 (21) | | 53 (21) |
| Cape May Warbler | 25 (10) | | 23 (9) |
| Yellow-rumped Warbler | 10 (4) | | 25 (10) |
| Mourning Warbler | 35 (14) | | 43 (17) |
| Rose-breasted Grosbeak | 20 (8) | | 25 (10) |
| Chipping Sparrow | 10 (4) | * | 30 (12) |

* $P < 0.05$

that the mean values between the first and second census were different (P < 0.05) for three of 22 comparisons (Table 5). The general pattern for these data were greater numbers of individuals and species observed on the first census as compared with the second (14 of 22 comparisons). All three significant differences observed were attributed to greater numbers of Yellow-bellied Flycatchers, Nashville Warblers, and Chestnut-sided Warblers on the second as compared with the first date. A slightly larger percentage of the total number of species was observed on census one than on census two (72% for date one and 67% for date two) and 38% of the species were observed on both censuses (Appendix B). Species observed on both days were the most common species and species observed on only one day were generally represented by only one or two individuals.

An important part of the analyses of data from day one and two as compared with the mean is whether the variance is reduced by censusing once or twice. That is, it is helpful to know how much a second census increases our ability to detect the desired difference for a particular parameter. We used the CV to compare the relative amounts of variation in populations having different means (Sokal and Rohl 1981). Because the CV is proportional to differences detectable between two means, we used the CV to guide our interpretations of the results. For the Wisconsin data, the CV was lower for either day for 9 parameters and lower for the mean of the two days for 12 parameters. When the CV was lower for one census date as compared with the mean, it was on average 11% lower. In contrast, when the CV was lower for the mean, it was on average 20% lower than either day. This 9% difference in CV's between one census and the mean of the two censuses allows the detection of about a 3% smaller difference between two means in statistical analyses (Figure 4).

Table 5. Mean observations, variance, coefficient of variation, and significance of paired t-tests between: (1) date one and two; (2) date one and the mean; and (3) date two and the mean for control and treatment transects in Wisconsin.

| Parameter | Date | Control | | | Treatment | | |
|---|---|---|---|---|---|---|---|
| | | X | $s^2$ | CV | X | $s^2$ | CV |
| Yellow-bellied | 3 June | - | - | - | 0.75 | 1.36 | 155 |
| Flycatcher | 8 June | - | - | - | 2.00 | 1.43 | 159 |
| | Mean | - | - | - | 1.38* | 1.13 | 77 |
| Least Flycatcher | 3 June | 4.63 | 18.49 | 93 | 0.38 | 1.13 | 280 |
| | 8 June | 2.25 | 3.61 | 84 | 0.00 | - | - |
| | Mean | 3.44 | 6.67 | 75 | 0.19 | 0.28 | 294 |
| Red-eyed Vireo | 3 June | 6.75 | 8.79 | 44 | 2.50 | 5.71 | 96 |
| | 8 June | 6.13 | 3.24 | 29 | 1.38 | 1.42 | 86 |
| | Mean | 6.44 | 2.10 | 23 | 1.94 | 2.53 | 82 |
| Nashville Warbler | 3 June | 2.13 | 1.44 | 56 | 10.50 | 17.43 | 40 |
| | 8 June | 3.37 | 2.79 | 50 | 7.88 | 12.96 | 46 |
| | Mean | 2.94 * | 1.39 | 40 | 9.19 | 12.25 | 38 |
| Chestnut-sided | 3 June | 0.50 | 0.57 | 151 | 1.50 | 9.67 | 207 |
| Warbler | 8 June | 2.50 | 1.98 | 56 | 0.88 | 2.99 | 196 |
| | Mean | 1.50 * | 0.49 | 47 | 1.19 | 5.71 | 200 |
| Black-throated- | 3 June | 4.88 | 3.24 | 37 | 0.63 | 0.84 | 145 |
| green Warbler | 8 June | 4.38 | 3.96 | 46 | 0.63 | 0.55 | 118 |
| | Mean | 4.63 | 0.98 | 21 | 0.63 | 0.63 | 126 |
| Ovenbird | 3 June | 7.63 | 5.69 | 31 | 4.75 | 17.07 | 87 |
| | 8 June | 8.00 | 5.71 | 30 | 3.50 | 9.43 | 88 |
| | Mean | 7.81 | 2.99 | 22 | 4.13 | 11.83 | 83 |
| Common | 3 June | 0.25 | 0.49 | 280 | 0.88 | 0.69 | 94 |
| Yellowthroat | 8 June | 0.13 | 0.13 | 277 | 1.00 | 4.01 | 200 |
| | Mean | 0.19 | 0.14 | 197 | 0.94 | 1.75 | 141 |
| White-throated | 3 June | - | - | - | 2.63 | 4.24 | 78 |
| Sparrow | 8 June | 0.88 | 1.84 | 154 | 3.00 | 2.29 | 50 |
| | Mean | 0.44 | 0.46 | 154 | 2.81 | 2.57 | 57 |
| Species | 3 June | 18.88 | 56.10 | 40 | 13.63 | 12.81 | 26 |
| | 8 June | 14.38 | 6.55 | 18 | 12.50 | 3.13 | 14 |
| | Mean | 16.63 | 19.36 | 26 | 13.06 | 6.67 | 20 |
| Individuals | 3 June | 45.50 | 185.40 | 30 | 39.25 | 87.37 | 24 |
| | 8 June | 39.25 | 23.04 | 12 | 32.25 | 14.21 | 12 |
| | Mean | 42.38 | 42.51 | 15 | 35.75 | 32.78 | 16 |

* P < 0.05 between date one and date two, date one and the mean, and date two and the mean
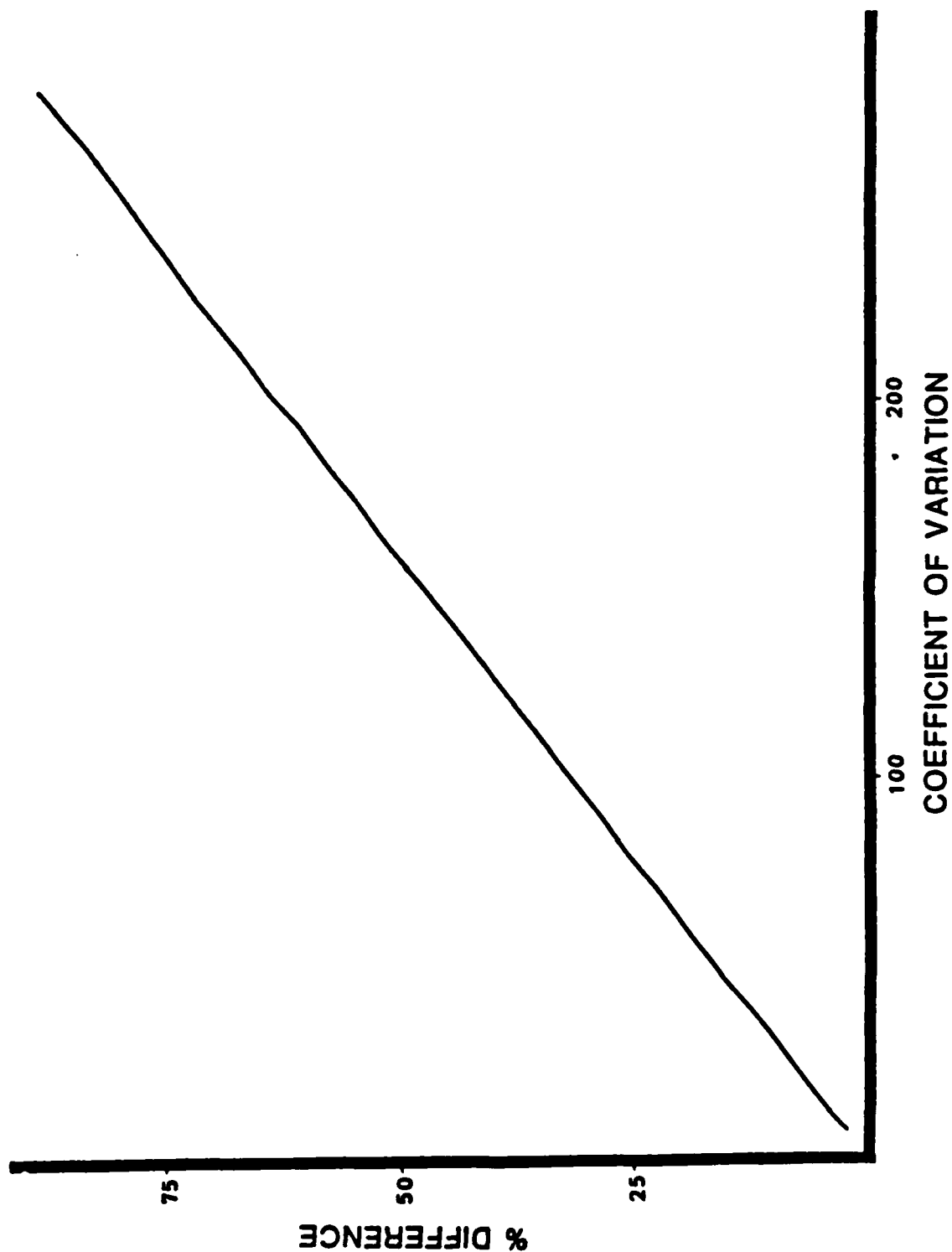
Figure 4. Relationship between coefficient of variation and percent difference detectable. Date are from several bird parameter means and variances for the Michigan and Wisconsin breeding data.

Michigan bird populations.   Eighty-one species and 2956 individuals were observed on all control and treatment transect segments in Michigan (Table 2).   Seventy-two species (mean = 13.9) and 1327 individuals (mean = 33.2) were sighted on control transect segments and 70 species (mean = 14.2) and 1629 individuals (mean = 40.7) were counted on treatment transects. Like in Wisconsin, the Ovenbird and Red-eyed Vireo were the most common species on both control and treatment transects (mean > 3.5 individuals/transect segment). The significant differences between control and treatment transect segments are summarized as follows (Table 6).   More (P < 0.05) individuals were observed on treatment than on control transect segments (mean = 40.7 and 33.2) but more Rose-breasted Grosbeaks were observed on control than treatment transects (mean = 1.3 and 0.8).   In contrast, the treatment transects had higher densities (P < 0.01) of Nashville Warblers (mean = 1.59 and 0.95), Chestnut-sided Warblers (mean = 1.18 and 0.57), Mourning Warblers (mean = 1.58 and 0.48) and White-throated Sparrows (mean = 1.93 and 0.88).   Results of the G-tests (Table 7) indicated that the Yellow-bellied Flycatcher and Golden-crowned Kinglet occurred more frequently (P < 0.05) on treatment (14 and 11 transect segments respectively) as compared with the control transect segments (6 and 3 transect segments respectively). However, the Winter Wren occurred on more (P < 0.05) control than treatment transect segments (15 versus 6).

Daily and observer variation in census data. Nine of 24 paired comparisons of bird population parameters were different (P < 0.05) between one census day and the mean of two censuses (Table 8).   More (P < 0.05) Least Flycatchers, Black-throated Green Warblers, and Rose-breasted Grosbeaks were observed on census day two than one.   In contrast, more (P < 0.05) Red-eyed Vireos, Chestnut-sided Warblers, Ovenbirds, species, and

Table 6. Mean observations in a 500 m transect and significance of one-way ANOVA between control and treatment transects for 11 bird species and two community parameters in Michigan.

| Parameter | Control | | Treatment |
|---|---|---|---|
| Least Flycatcher | 1.20 | | 0.85 |
| Black-capped Chickadee | 1.10 | | 1.00 |
| Hermit Thrush[1] | 1.15 | | 0.98 |
| Red-eyed Vireo | 3.60 | | 4.63 |
| Nashville Warbler[1] | 2.40 | ** | 5.70 |
| Chestnut-sided Warbler[1] | 1.45 | ** | 4.10 |
| Black-throated-green Warbler | 2.55 | | 1.75 |
| Ovenbird | 6.03 | | 6.50 |
| Mourning Warbler | 0.48 | * | 1.58 |
| Rose-breasted Grosbeak | 1.30 | * | 0.75 |
| White-throated Sparrow | 0.88 | ** | 1.93 |
| Species | 13.98 | | 14.23 |
| Individuals[1] | 33.28 | ** | 40.78 |

[1] Log transformed before analyses

* $P < 0.05$

** $P < 0.01$

Table 7. Percent and absolute number in parenthesis of total transect segments where each species was observed and significance of a G-test between control and treatment transects in Michigan (n = 40).

| Parameter | Control | | Treatment |
|---|---|---|---|
| Yellow-bellied Sapsucker | 23 (9) | | 18 (7) |
| Common Flicker | 15 (6) | | 20 (8) |
| Eastern Wood Peewee | 18 (7) | | 33 (13) |
| Yellow-bellied Flycatcher | 15 (6) | * | 35 (14) |
| Great Crested Flycatcher | 35 (14) | | 23 (9) |
| Blue Jay | 58 (23) | | 48 (19) |
| Red-breasted Nuthatch | 43 (17) | | 33 (13) |
| White-breasted Nuthatch | 20 (8) | | 15 (6) |
| Winter Wren | 38 (15) | * | 15 (6) |
| Golden-crowned Kinglet | 8 (3) | * | 28 (11) |
| Veery | 33 (13) | | 25 (10) |
| American Robin | 43 (17) | | 48 (19) |
| Cedar Waxwing | 23 (9) | | 8 (3) |
| Black-and-white Warbler | 63 (25) | | 48 (19) |
| Common Yellowtnroat | 20 (8) | | 18 (7) |
| Canada Warbler | 8 (3) | | 13 (9) |

* $P < 0.05$

Table 8. Mean observations, variance, coefficient of variation, and significance of paired t-tests between: (1) date one and two; (2) date one and the mean; and (3) date two and the mean for control and treatment transects in Michigan.

| Parameter | Date | Control | | | Treatment | | |
|---|---|---|---|---|---|---|---|
| | | X | $s^2$ | CV | X | $s^2$ | CV |
| Least Flycatcher | 14 June | 0.63 | 0.55 | 118 | 1.25 | 2.49 | 126 |
| | 20 June | 1.88 | 3.24 | 96 | 1.75 | 10.49 | 185 |
| | Mean | 1.25 * | 1.34 | 93 | 1.50 | 5.06 | 150 |
| Black-capped | 14 June | 1.25 | 3.61 | 152 | 1.13 | 0.69 | 74 |
| Chickadee | 20 June | 0.63 | 0.83 | 145 | 1.63 | 2.25 | 92 |
| | Mean | 0.94 | 2.05 | 152 | 1.38 | 1.43 | 86 |
| Hermit Thrush | 14 June | 0.63 | 3.13 | 280 | 0.63 | 0.55 | 118 |
| | 20 June | 0.88 | 0.98 | 112 | 1.25 | 0.78 | 71 |
| | Mean | 0.75 | 1.77 | 177 | 0.94 | 0.32 | 60 |
| Red-eyed Vireo | 14 June | 3.38 | 17.12 | 122 | 10.50 | 4.00 | 19 |
| | 20 June | 4.50 | 8.28 | 64 | 5.50 | 15.68 | 72 |
| | Mean | 3.94 | 11.53 | 86 | 8.00 * | 4.36 | 26 |
| Nashville Warbler | 14 June | 1.63 | 3.98 | 122 | 4.25 | 0.49 | 16 |
| | 20 June | 2.25 | 8.21 | 127 | 2.25 | 19.89 | 198 |
| | Mean | 1.94 | 4.82 | 113 | 3.25 | 5.78 | 74 |
| Chestnut-sided | 14 June | 0.88 | 2.99 | 196 | 8.50 | 4.54 | 25 |
| Warbler | 20 June | 1.88 | 5.80 | 128 | 2.88 | 9.24 | 106 |
| | Mean | 1.38 | 3.91 | 143 | 5.69 * | 1.99 | 25 |
| Black-throated | 14 June | 1.00 | 1.69 | 130 | 3.25 | 2.49 | 49 |
| Green Warbler | 20 June | 2.75 | 3.92 | 72 | 2.75 | 6.50 | 93 |
| | Mean | 1.88 * | 1.77 | 71 | 3.00 | 2.86 | 56 |
| Rose-breasted | 14 June | 1.50 | 2.29 | 100 | 0.63 | 0.55 | 118 |
| Grosbeak | 20 June | 1.88 | 1.84 | 72 | 2.50 | 4.57 | 86 |
| | Mean | 1.69 | 0.99 | 99 | 1.56 * | 1.74 | 85 |
| Ovenbird | 14 June | 6.00 | 12.25 | 58 | 11.50 | 1.43 | 10 |
| | 20 June | 5.50 | 17.64 | 76 | 7.00 | 15.36 | 56 |
| | Mean | 5.75 | 14.06 | 65 | 9.25 * | 4.84 | 24 |
| White-throated | 14 June | 2.13 | 6.15 | 116 | 1.13 | 3.24 | 160 |
| Sparrow | 20 June | 3.50 | 10.56 | 93 | 2.25 | 20.70 | 202 |
| | Mean | 2.81 | 7.34 | 96 | 1.69 | 4.54 | 126 |
| Species | 14 June | 15.25 | 15.64 | 26 | 16.38 | 6.84 | 16 |
| | 20 June | 13.13 | 13.56 | 28 | 11.75 | 12.50 | 30 |
| | Mean | 14.19 * | 13.61 | 26 | 14.06 * | 2.53 | 11 |
| Individuals | 14 June | 35.50 | 20.57 | 13 | 55.88 | 21.80 | 8 |
| | 20 June | 35.88 | 20.41 | 13 | 38.00 | 43.14 | 17 |
| | Mean | 35.69 | 10.89 | 9 | 46.94 * | 12.53 | 8 |

* $P < 0.05$

** $P < 0.01$

individuals were observed on census day one. Like in Wisconsin, a larger percentage of the total number of species was observed on census one than on census two (77% for census one and 61% for census two) and 38% of the species were observed on both censuses (Appendix C). The CV's were less than or equal to the mean for one census for 15 of 24 parameters and greater than the mean of the two censuses for 9 parameters. When the CV was lower for one census than the mean, it was 21% lower. In contrast, when the CV was lower for the mean than either census day, it was only 6% lower. This average difference of 15% in the CV's results in a difference in our ability to detect a 5% smaller difference between two means when only one census is conducted as compared with two censuses (Figure 4).

Observed versus predicted data.--The mean number of species observed during the breeding season on a 500 m transect segment was slightly higher than what we predicted prior to this study [14 versus 12 (Table 9)]. The variance of the breeding data was also higher than what we predicted (10 in Michigan, 14 in Wisconsin, and 8 predicted). Despite these differences, the predicted and observed differences that we specified prior to the study were almost equal for species richness (8% in Wisconsin, 7% in Michigan, and 7% predicted).

The pattern for relative density of the bird community was identical to that of species richness. The variances of the breeding densities were higher than we predicted (36 in Wisconsin, 37 in Michigan, and 21 predicted), but the percent differences that we could detect between control and treatment areas were only slightly higher than we predicted (8% for Michigan, 7% for Wisconsin, 6% predicted).

We predicted that we could detect a 16% difference between two means for a species that occurred with a mean of 5 individuals in a transect

Table 9. Means and variance for bird population data in Wisconsin and Michigan during the 1985 breeding seasons. We used the equation: $N = 4S^2 / D^2$ from Snedecor and Cochran (1979) where $N = 40$ to calculate actual differences detectable ($P < 0.05$) between the control and treatment means and $N = 80$ where data from states were combined.

| Parameter number/500 m transect | State | Mean | Variance of sample data $S^2$ | Actual and percent difference detectable between two means | |
|---|---|---|---|---|---|
| | | | | N = 40 | N = 80 |
| Species richness as | Wisconsin | 14.0 | 14.1 | 1.19 (9) | |
| number of species | Michigan | 14.1 | 9.8 | 0.98 (7) | |
| | Predicted | 12.0 | 8.0 | 0.89 (7) | 0.77 (5) |
| Relative density as | Wisconsin | 35.2 | 67.2 | 2.59 (7) | |
| number of individuals | Michigan * | 37.0 | 89.7 | 2.99 (8) | |
| | Predicted | 21.0 | 14.0 | 1.18 (6) | 1.98 (5) |
| Red-eyed Vireo | Wisconsin | 4.5 | 10.3 | 1.01 (22) | |
| | Michigan | 4.1 | 14.0 | 1.18 (29) | |
| | Predicted | 6.0 | 9.0 | 0.95 (16) | 0.76 (17) |
| Nashville Warbler | Wisconsin | 3.7 | 17.6 | 1.32 (35) | |
| | Michigan * | 4.1 | 17.4 | 1.32 (32) | |
| | Predicted | 6.0 | 9.0 | 0.95 (16) | 0.94 (24) |
| Ovenbird | Wisconsin | 6.5 | 21.2 | 1.45 (22) | |
| | Michigan | 6.3 | 18.5 | 1.36 (21) | |
| | Predicted | 6.0 | 9.0 | 0.95 (16) | 0.98 (15) |
| Chestnut-sided Warbler | Wisconsin | 1.5 | 4.8 | 0.69 (46) | |
| | Michigan * | 2.8 | 13.4 | 1.15 (41) | |
| | Predicted | 6.0 | 9.0 | 0.95 (16) | 0.67 (31) |
| Black-throated Green | Wisconsin | 2.8 | 4.8 | 0.69 (25) | |
| Warbler | Michigan | 2.2 | 4.8 | 0.69 (32) | |
| | Predicted | 6.0 | 9.0 | 0.95 (16) | 0.49 (19) |

* log transformed before analyses

segment. However only one species, the Ovenbird, occurred in the study areas at that density. Therefore, the percent differences detectable between two means were higher than what we predicted for most species but the actual differences were lower (Table 9). The Ovenbird had a density of < 6 individuals/500 m transect and we could detect a 20% difference between control and treatment transects in either state. More importantly, all ANOVA tests illustrated that we **could** detect the differences that we calculated in the actual statistical analyses (Tables 3, 5, 9). For example, with the observed data in Wisconsin, we calculated that a difference of 0.7 Chestnut-sided Warblers between control and treatment transects would be statistically significant (P < 0.05). Results showed that a mean of 1.0 and 2.0 individuals were observed on control and treatment transects or a difference of 1.0 and this difference was significant (Table 3).

## DISCUSSION

Isolating effects of electromagnetic fields. This investigation was designed to isolate and assess the effects of extremely low frequency electromagnetic fields on breeding bird populations. The two potential approaches for this assessment are to: (1) compare the affected area (treatment) with a similar control area; or (2) conduct a before-and-after type study. Because the antenna is not operating in Michigan, a before-and-after investigation is planned. In Wisconsin no pre-impact data are available and we cannot assume that the antenna system has not already altered the bird community. Consequently, we cannot pair transect segments based on similarities in bird species communities, but we can pair study areas on the basis of similar habitat features. Our rationale for using this method is that birds select their breeding areas on the basis of

vegetation structure (Lack 1933; Hilden 1965; James 1977) and therefore, areas of similar vegetation should also have the most similar bird communities. We will quantitatively assess the habitat characteristics of all control and treatment transects in Wisconsin. This will allow us to pair control and treatment transect segments based on their habitat similarity. It is likely that not all transect segments can be paired, but the strength of this approach is that we can define the most similar control and treatment areas, exclude those that are not suitable, and most importantly, isolate the effects of the electromagnetic field by controlling for potential differences between control and treatment area habitat characteristics.

We will sample the vegetation on all 80 control and treatment transect segments in Wisconsin in 1986 and 1987. Samples will be collected at random distances laterally from the transect center line to avoid any biases in where the flag markers for the transects were placed. We will use methods that we have successfully used in past investigations to assess the habitat characteristics of the study transects (Niemi and Hanowski 1984; Niemi 1985) which were modified from Wiens (1969) and Wiens and Rotenberry (1981). The vegetation variables that will be measured include: (1) tree (a) densities, (b) heights, (c) diameters, and (d) species composition; (2) canopy cover; (3) ground cover; (4) water cover and depth; (5) shrub (a) heights, (b) densities, and (c) species composition; (6) forb (a) densities and species composition; (7) graminoid (sedge and grass) density; and (8) overall height of the vegetation. Densities of trees, shrubs, forbs, and graminoids will be calculated with the use of the point-centered quarter method (Cottam and Curtis 1956). This method will also provide estimates for tree basal area, dominance, and frequency of

each tree species. Water depth and shrub height will be measured with a meter stick and tree and overall height with a clinometer. Canopy, ground, and percent water cover will be estimated. These data will be analyzed with multivariate statistical techniques (e.g., principal component analysis and discriminant function analysis) to assess similarities and differences in habitat characteristics at each sample point and for combinations of points for each transect segment. These methods will allow us to match similar control and treatment transect segments.

Vegetation samples will be collected at 25 m intervals to describe changes that occur along each transect segment. The field data will be collected over a two year period to more efficiently use personnel and to better control for seasonal variation in vegetation growth. For example, a total of 1600 points will be measured. We could measure all sites in one season, but this would require a larger field crew (8 individuals) and a longer sampling period (May to September). A smaller crew (4 individuals) and shorter sampling period (late-June to August) will reduce the potential variation attributable to vegetation growth in contrast with a longer sampling period. A representative portion of the plots measured in 1986 will be remeasured in 1987 to quantify annual differences in vegetation growth. If differences exist, they will be accounted for in the final data analyses and the matching of control and treatment plots.

Sample size requirements. A major objective for this year was to determine whether the sample size was adequate to detect our predicted a priori differences between control and treatment transects ' r species richness, total density, density of a common species, an density of uncommon species. Differences detectable between control and treatment transects for species richness and total density are almost equal to what we predicted.

For common species the percent difference detectable between control and treatment means ranged from 21-41% and this is slightly higher than what we anticipated. This discrepancy is due mainly to the lower densities of "common species" that we observed as compared with the densities we predicted. The percent differences detectable between two means in our statistical analyses are inversely proportional to the magnitude of the mean, but the actual differences detectable are proportional to the variance. For example, the variance (4.8) and actual difference detectable (0.69) for the Black-throated Green Warbler were equal for Michigan and Wisconsin. However, because the mean for Michigan was lower than the mean in Wisconsin (2.2 versus 2.8) we could detect a 25% difference in Wisconsin as compared with a 32% difference in Michigan. For these data it may be more appropriate to relate the actual difference detectable between two means to our goal of wanting to detect a difference of one individual between control and treatment areas. If we examine the data in this light, we find that on average we can detect a difference of 1.09 individuals between control and treatment means and this is consistent with our goal of detecting a difference of about one individual between control and treatment areas.

It may be possible to detect smaller percent differences between means for all parameters by using paired comparisons in statistical analyses. For example, we used a completely randomized block (ANOVA) design which is equivalent to a t-test (Sokal and Rohlf 1981) to compare control and treatment transects in each state. However, it is possible to pair similar control and treatment transects in Wisconsin (matched by habitat characteristics) and Michigan (matched by bird population characteristics) and use a paired test. A randomized block (paired comparisons) design is more powerful and efficient than a t-test because it allows us to estimate

the added variance component among the transect segments (Sokal and Rohlf 1981). One potential drawback to using the paired design is that not all control and treatment transect segments can be suitably paired and this would decrease the sample size. We will experiment with both approaches to determine the suitability of each design in future analyses after the transects have been paired. In addition, based on the similarity in bird populations between states, we will explore the possibility of combining data between states. This would increase the sample size and the power of the statistical analyses. For example, with the combined information and sample size of 80, we predict that a 5% difference in species richness and total density will be detectable between control and treatment transects and on average a 21% difference for common species.

For uncommon species, we were able to detect a 20% difference in the frequency of species occurrence on control as compared with treatment transects with a G-test. A larger sample size will most likely provide a more accurate frequency distribution for uncommon species and will allow us to test for differences between more species. We will also be able to examine suites of species with some common feature (e.g., similar habitat affinity or foraging tactics) and determine whether these groups show any patterns in avoidance or attraction to the antenna.

Number of censuses required. It is well known that the magnitude of the variation for a parameter is directly proportional to the differences that are detectable between two means. In this study there are at least three sources of variation in the data collected: (1) inherent or natural variation of populations; (2) daily variation in the number of individuals or species detected; and (3) observer variability. Our data collection methods were designed to control for daily and observer variation. For

example, we controlled for daily variation in bird detection by censusing control and treatment transects simultaneously. Likewise, differences between observers were controlled for in the experimental design because each observer is randomly assigned to the census area and each observer censused the same number of control and treatment transects (Dawson et al. 1978).

We originally planned to census each transect twice during the breeding season and to use the mean number of observations in our analyses. We felt that this approach would provide the best estimate of species densities and also reduce the amount of variation. This year we were only able to census each transect once and selected transects twice. However, this provided some insight on what additional information is gained with a second census and whether a second census actually increases our ability to detect differences. Results from the data on transects censused on two dates indicated that there were differences between day one and day two in both states. This is not unusual or unexpected because detection of birds during the breeding season is almost exclusively based on bird song which is affected by many intrinsic (e.g., synchronony of the nesting stage) and extrinsic (e.g., temperature) factors (Slagsvold 1973; Emlen 1984). In addition, even highly trained observers differ in their abilities to detect and record audible bird cues (Berthold 1976; Svensson 1977; Kavanagh and Recner 1983; Bart and Schoultz 1984). Again, we emphasize that these two factors are controlled for in the experiment.

We initially projected that by censusing each transect twice we would reduce the variance of the bird population parameters of interest. However, data from this year indicated that two censuses decreased the CV slightly in Wisconsin, but the CV was higher on average for the Michigan

data. A second census did not reduce the variation in these data and this is probably because we are adding intrinsic and extrinsic sources of variation to the data when two censuses are conducted (daily and observer variation). Based on this information, each transect will be censused once during the breeding season. To furthur explore the effect of observer variability, we will place more emphasis on standardizing data collected between observers. This will be done in 1986 when the same transects will be censused simultaneously by observers and detection factors for each observer will be standardized (see Svensson 1977).

Bird populations. Results of the breeding data will not be interpreted until we have collected post-impact data in Michigan. However, it appears that patterns of bird populations and community parameters are similar for Wisconsin and Michigan and are consistent between control and treatment transects between states. For example, a total of 7 differences were detected between control and treatment transects in Wisconsin and 9 were observed in Michigan. Two of these differences in each state were higher densities on control as compared with treatment transects and 5 and 7 (Wisconsin and Michigan respectively) differences indicated that treatment transect densities were higher than control transect densities. An even more interesting comparison is that about one third of the differences observed between control and treatment transects were consistent between states. For example, more Winter Wrens were observed on control transects in both states while more individuals and more Chestnut-sided Warblers were observed on treatment transects as compared with control transects in both states. These data provide additional support for combining data from states and for using results in Michigan to interpret possible effects in Wisconsin.

<u>Migratory</u> <u>bird</u> <u>population</u> <u>study.</u> Field investigations to determine effects of an extremely low frequency (ELF) antenna system on some aspects of a bird species life history are currently underway (IITRI 1985) and these investigations will provide information on selected parameters such as physiology (e.g., growth and metabolic rate), behavior (e.g., homing), and populations (e.g., species richness and density) of bird species. These studies do not specifically address the possible effect of the antenna system on populations of birds migrating through areas adjacent to the antenna system or the timing of bird migration (e.g., arrival and departure time of migrating species). Because migrating birds use the earth's magnetic field to aid in their migration (Emlen 1975), magnetic fields produced by extremely low frequency communications systems may affect their ability to migrate (Alterstam and Hogstedt 1983). Previous investigations on the effects of extremely low frequency electromagnetic fields on migrating birds at the Wisconsin ELF site have reported mixed results. A negative effect was reported by Southern (1972, 1975) and Larkin and Sutherland (1977), but no effect was reported by Williams and Williams (1976) for migrating birds detected by radar.

Several questions can be considered to determine whether extremely low frequency electromagnetic fields affect an individual birds' ability to migrate. For example, one question would be to determine whether an individual exposed to ELF sources during ontongeny could successfully migrate south and then return to its natal area. At least three different investigations could be conducted to address this question: (1) a banding study of a migrant bird species; (2) long-distance radio-tracking of individual birds; or (3) an assessment of seasonal bird population levels. Method one, a banding study is being conducted by Beaver et al. (1985) in Michigan as part of their investigation to assess behavioral and

physiological effects of the ELF antenna on tree swallows. Their major objective was not specifically to address return rate differences between test and control areas, but they state "we should be able to determine return rates and site tenacity from year to year, although variability is generally too high to meet any criteria of statistical sufficiency" (Beaver et al. 1985). Because of the high variability and low return rates for passerine birds, a banding study that would specifically assess and test differences in return rates would require a large sample size (Table 10). An investigation of this type would address only one parameter (return rate) for one species which is not likely indicative of all populations of bird species that are potentially affected. Method two, a long-distance radio-tracking study would be very experimental, the data would be difficult to obtain, and certainly expensive. Like a banding study, radio-tracking would likely provide data on one parameter and only for one or two species.

With this brief rationale, we will concentrate additional efforts on method three (above) and on two major questions regarding the potential effects that the ELF electromagnetic fields may have on migrating and migrant bird populations. Specifically: (1) are there effects of the ELF antenna system on populations of birds migrating in proximity to the antenna system; and (2) are life history characteristics (e.g., arrival and departure) of migrant bird populations effected by ELF electromagnetic fields? The specific parameters that will be tested are: (1) species richness of the bird community; (2) relative density of the bird community; (3) relative density of common species; (4) relative frequency of specific migrant species; and (5) arrival and departure dates of migrant species. We will test these parameters between treatment areas

Table 10. Sample size, and estimated cost to obtain sample size to detect a 15% difference between a control and treatment. Sample size was calculated using the equation: $V^2 = 2S^2 / N$ defined by Kish (1965).

| Parameter | Estimated Mean | Estimated Variance | Sample Size | Estimated cost/ Year |
|---|---|---|---|---|
| 1. Return rate for young birds | 0.2 | 0.1 | 1500 | > 300,000 |
| 2. Radio-tracking* (days to reach wintering grounds) | ? | ? | ? | > 500,000 |
| 3. Population parameters (e.g. species richness) | 6.1 | 0.8 | 80 | < 100,000 |

* Comparable data for an investigation of this type are not available

adjacent to the ELF system and control areas away from the influence of ELF electromagnetic fields. We focus our efforts on these questions because: (1) sufficient data can be collected to provide reliable statistical results for the population parameters in question; (2) we have already collected preliminary data to address these questions; (3) we can use our existing study transects which represent an efficient use of time and effort; and (4) this effort is complimentary to our present work on breeding bird populations.

The basic rationale for this portion of the project is, if there is an effect of the ELF antenna system on bird migration, then these effects should be detectable by observed differences in the number of birds moving through the ELF antenna areas and suitable control areas. If the ELF system is attracting birds, then migrant populations would be higher along the antenna system. If the antenna is repulsing birds, then lower populations would be observed near the antenna system as compared with the control sites. A random pattern of higher and lower populations between control and treatment areas would likely by symptomatic of no effect of the ELF antenna system. In addition, we can examine species differences in arrival and departure dates to and from the control and treatment areas.

To determine the sample size necessary to detect reasonable differences in the variables of interest, we originally used estimates of the variance available in the literature and our unpublished data. These estimates were based on breeding data because data for migration were not available. We now have data for the fall migration in 1984 and breeding data from 1985 from our study sites and we present levels of detectability in tabular form for the respective variables (Table 11). In general, we can detect about a 15% difference in the number of individuals migrating and in the number of species. This translates into a difference of about

Table 11. Means and variance for bird population data in Wisconsin and Michigan during the 1984 fall migration. We used the equation: $N = 4S^2 / D^2$ from Snedecor and Cochran (1979) where $N = 40$ to calculate actual differences detectable between the control and treatment means.

| Parameter number/500 m transect | State | Mean $\bar{X}$ | Variance of sample data $S^2$ | Actual and percent difference detectable between two means |
|---|---|---|---|---|
| Species richness as | Wisconsin | 6.1 | 9.8 | 0.99 (16) |
| number of species | Michigan | 6.1 | 7.2 | 0.85 (14) |
| Relative density as | Wisconsin | 15.0 | 72.2 | 2.68 (18) |
| number of individuals | Michigan | 17.7 | 177.0 | 4.21 (24) |
| Black-capped Chickadee | Wisconsin* | 0.8 | 0.8 | 0.28 (35) |
| | Michigan | 2.2 | 9.7 | 0.98 (45) |
| Red-breasted Nuthatch | Wisconsin* | 0.9 | 0.7 | 0.16 (18) |
| | Michigan | 1.7 | 4.8 | 0.69 (41) |
| Red-eyed Vireo | Wisconsin* | 0.3 | 0.3 | 0.17 (58) |
| | Michigan* | 0.7 | 0.7 | 0.26 (38) |
| Ovenbird | Wisconsin | 1.3 | 2.9 | 0.53 (41) |
| | Michigan* | 0.6 | 0.5 | 0.22 (37) |

* log transformed

one species (0.15 X 6 = 0.9) that we could detect if such a difference exists between control and treatment areas. In terms of an individual species, we project that we could detect between 18 and 58% (mean = 39%) differences in populations of migratory birds. Differences of 58% may seem like a relatively low level of detectability, but this translates into the ability to detect relatively subtle differences in species specific populations. For example, our projection is that we could detect a decrease or an increase of 0.18 individuals/500 m transect segment from a mean of 0.31 individuals/500 m transect segment. Given the high variation associated with migration data, we believe that these levels of differences are reasonable for the parameters of interest.

We will census each 500 m transect segment (160 total) four times during the periods of most-intense migratory activity in the study areas. The census data will be gathered during the following periods in each state: (1) one census in May to assess the use of these areas by spring migrating birds; (2) one census in July to document recruitment of young birds and percentage of population that is still actively defending territories; (3) one census in August to document additional recruitment of young birds, percentage of population that is still actively defending territories, plus the assessment of early-fall migrating birds; and (4) one census in September to identify late-fall migrating birds. Together with our breeding bird work, each transect will be censused five times during the period of time that a species arrives and then departs from the breeding area. The data will be analyzed with methods described previously for the breeding data.

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# Appendix A

Summary of original and revised EM

measurements in Wisconsin and Michigan.

Table 1.  Original IITRI transect number, site name, and location of transects
Wisconsin and Michigan.  IITRI transect numbers are used throughout
appendix A.

| IITRI Transect No. | Investigator's Site Name | Location | | |
|---|---|---|---|---|
| | | Township | Range | Section(s) |
| **Michigan** | | | | |
| 10C1 | Carney Lake | 41N | 29W | 33,34,35 |
| 10C2 | Skunk Creek | 42N | 28W | 14,23,24 |
| | | 42N | 27W | 19,30 |
| 10C3 | Ralph South | 43N | 28W | 12 |
| | | 43N | 27W | 7,8,9 |
| 10C4 | Ralph North | 43N | 28W | 1 |
| | | 43N | 27W | 4,5,6 |
| 10C5 | Arnold | 43N | 28W | 31,32,33,34 |
| 10T1 | Leeman's Road | 43N | 29W | 14,23,26,35 |
| 10T2 | Turner Road | 43N | 29W | 1,11,12 |
| | | 44N | 29W | 36 |
| 10T3 | Flat Rock Creek | 44N | 28W | 6 |
| | | 45N | 28W | 19,30,31 |
| 10T4 | Schwartz Creek | 45N | 28W | 31 |
| | | 45N | 29W | 26,27,35,36 |
| 10T5 | Birch Lake | 43N | 29W | 13,24,25 |
| **Wisconsin** | | | | |
| 10C6 | Spillerberg Lake | 43N | 3W | 23,26,35 |
| 10C7 | Mineral Lake | 44N | 4W | 9,10,17 |
| 10C8 | Moose Lake | 41N | 6W | 20,29,32 |
| 10C9 | Blaiselell Lake | 40N | 3W | 18 |
| | | 40N | 4W | 13,14,22,23 |
| 10C10 | Brunet River | 40N | 3W | 16,21,29 |
| 10T6 | Moose River | 42N | 3W | 31 |
| | | 42N | 4W | 35,36 |
| 10T7 | Christy Lake | 42N | 5W | 7,8,15,16,17 |
| 10T8 | Little Clam Lake | 42N | 4W | 5,18,17 |
| | | 43N | 4W | 33,32 |
| 10T9 | Woodtick Lake | 43N | 4W | 22,23,27,28,33 |
| 10T10 | Black Lake | 41N | 5W | 24,25,36 |

Table 2. Electric field intensities and magnetic flux densities[1] for original Michigan transects.

| Site No. | Meas. Pt. | Meas. Yr. | Transverse E Field (Air), V/M | | Longitudinal E Field (Earth), mV/M | | Magnetic Flux Density, mG | |
|---|---|---|---|---|---|---|---|---|
| | | | 76 Hz | 60 Hz | 76 Hz | 60 Hz | 76 Hz | 60 Hz |
| 10C1 | 1 | 1984 | <0.001 | -- | 0.50 | 0.61 | 0.025 | 0.011 |
| 10C1 | 2 | 1984 | <0.001 | -- | 0.50 | 0.62 | 0.025 | 0.001 |
| 10C2 | 1 | 1984 | <0.001 | -- | 2.0 | 0.98 | 0.036 | 0.005 |
| 10C2 | 2 | 1984 | <0.001 | -- | 1.0 | 0.35 | 0.028 | 0.003 |
| 10C3 | 1 | 1984 | <0.001 | -- | 4.5 | 0.09 | 0.038 | <0.001 |
| 10C3 | 2 | 1984 | <0.001 | -- | 3.0 | 0.02 | 0.026 | <0.001 |
| 10C4 | 1 | 1984 | <0.001 | -- | 6.0 | 0.06 | 0.038 | <0.001 |
| 10C5 | 1 | 1984 | <0.001 | 0.34 | 0.50 | 1.40 | 0.009 | 0.56 |
| 10C5 | 2 | 1984 | <0.001 | -- | 0.50 | 0.35 | 0.009 | 0.008 |
| 10C5 | 3 | 1984 | <0.001 | -- | 0.50 | 0.11 | 0.008 | 0.001 |
| 10T1 | 1 | 1984 | 0.05-0.5 | -- | 48.0 | 0.08 | 2.5 | 0.006 |
| 10T1 | 2 | 1984 | 0.05-0.5 | -- | 48.0 | 0.08 | 2.5 | 0.006 |
| 10T2 | 1 | 1984 | 0.05-0.5 | <0.001 | 48.0 | 0.42 | 2.5 | 0.002 |
| 10T2 | 2 | 1984 | 0.05-0.5 | -- | 48.0 | 0.22 | 2.5 | <0.001 |
| 10T2 | 3 | 1984 | 0.05-0.5 | <0.001 | 48.0 | 0.27 | 2.5 | <0.001 |
| 10T3 | 1 | 1984 | 0.05-0.5 | -- | 48.0 | 0.30 | 2.5 | <0.001 |
| 10T3 | 2 | 1984 | 0.05-0.5 | -- | 48.0 | 0.26 | 2.5 | <0.001 |
| 10T4 | 1 | 1984 | 0.05-0.5 | -- | 48.0 | 0.29 | 2.5 | <0.001 |
| 10T4 | 2 | 1984 | 0.05-0.5 | -- | 48.0 | 0.45 | 2.5 | <0.001 |
| 10T5 | 1 | 1984 | 0.05-0.5 | -- | 48.0 | 1.17 | 2.5 | 0.002 |
| 10T5 | 2 | 1984 | 0.05-0.5 | -- | 48.0 | 0.34 | 2.5 | 0.003 |

[1] Data listed for 76 Hz is estimated based on analysis using the proposed location and operating conditions of the antenna elements along with the distance to each measurement point.

[2] Values shown are magnitudes determined as the square root of the sum of the square of the orthogonal field components.

Table 3. Electric field intensities and magnetic flux densities[1,2] for original Wisconsin transects.

| Site No. | Meas. Pt. | Meas. Yr. | Transverse E Field (Air), V/M | | Longitudinal E Field (Earth), mV/M | | Magnetic Flux Density, mG | |
|---|---|---|---|---|---|---|---|---|
| | | | 76 Hz | 60 Hz | 76 Hz | 60 Hz | 76 Hz | 60 Hz |
| 10C6 | 1 | 1984 | -- | -- | 2.70 | 0.06 | 0.021 | 0.001 |
| 10C6 | 2 | 1984 | -- | -- | 3.50 | 0.10 | 0.026 | <0.001 |
| 10C7 | 1 | 1984 | <0.001 | <0.001 | 1.26 | 0.87 | 0.008 | <0.001 |
| 1CC7 | 2 | 1984 | -- | -- | 0.90 | 0.05 | 0.010 | <0.001 |
| 10C8 | 1 | 1984 | -- | -- | 6.50 | 0.34 | 0.025 | <0.001 |
| 10C8 | 2 | 1984 | -- | -- | 7.98 | 0.70 | 0.027 | 0.002 |
| 10C9 | 1 | 1984 | -- | -- | 1.60 | 0.10 | 0.047 | 0.001 |
| 10C9 | 2 | 1984 | -- | -- | 2.52 | 0.01 | 0.037 | <0.001 |
| 10C10 | 1 | 1984 | -- | -- | 2.52 | 0.02 | 0.031 | <0.001 |
| 10C10 | 2 | 1984 | -- | -- | 0.61 | 0.03 | 0.015 | <0.001 |
| 10T6 | 1 | 1984 | 0.201 | <0.001 | 136.0 | 0.04 | 3.64 | <0.001 |
| 10T6 | 2 | 1984 | 0.121 | 0.014 | 99.8 | 0.02 | 7.57 | 0.001 |
| 10T7 | 1 | 1984 | -- | -- | 200.2 | 0.04 | 4.76 | 0.001 |
| 10T7 | 2 | 1984 | 0.170 | <0.001 | 153.0 | 0.10 | 2.36 | <0.001 |
| 10T7 | 3 | 1984 | 0.195 | <0.001 | 179.0 | 0.10 | 4.99 | 0.001 |
| 10T8 | 1 | 1984 | 0.052 | <0.001 | 49.2 | 0.05 | 4.11 | 0.002 |
| 10T8 | 2 | 1984 | 0.102 | <0.001 | 117.0 | 0.05 | 5.40 | 0.001 |
| 10T9 | 1 | 1984 | 0.071 | 0.050 | 58.8 | 2.20 | 4.13 | <0.001 |
| 10T9 | 2 | 1984 | 0.474 | <0.001 | 463.5 | 0.13 | 1.53 | <0.001 |
| 10T10 | 1 | 1984 | 0.101 | <0.001 | 83.5 | 0.04 | 4.56 | 0.001 |
| 10T10 | 2 | 1984 | 0.201 | <0.001 | 156.5 | 0.09 | 4.98 | 0.001 |

[1] Values shown are magnitudes determined as the square root of the sum of the squares of the orthogonal field components measured.

Table 4. Revised transect number, site name, and location of transects in
Wisconsin and Michigan.

| IITRI Transect No. | Investigator's Transect Name | Location | | |
|---|---|---|---|---|
| | | Township | Range | Section(s) |
| | **Michigan** | | | |
| 10C1 | Carney Lake | 41N | 29W | 33,34,35,36 |
| 10C2 | Skunk Creek | 42N | 28W | 14,23,24 |
| | | 42N | 27W | 19,30 |
| 10C5 | Arnold | 43N | 25W | 31,32,33,34 |
| 10C12 | Lost Lake | 41N | 29W | 21,26,27,28,35 |
| 10C13 | Bob's Creek | 44N | 26W | 13,23,24,26 |
| 10T1 | Leeman's Road | 43N | 29W | 14,23,26,35 |
| 10T2 | Turner Road | 43N | 29W | 1,11,12 |
| | | 44N | 29W | 36 |
| 10T3 | Flat Rock Creek | 44N | 28W | 6 |
| | | 45N | 28W | 19,30,31 |
| 10T4 | Schwartz Creek | 45N | 28W | 31 |
| | | 45N | 29W | 26,27,35,36 |
| 10T11 | Heart Lake | 45N | 28W | 7,18 |
| | | 46N | 29W | 1 |
| | **Wisconsin** | | | |
| 10C6 | Spillerberg Lake | 43N | 3W | 23,26,35 |
| 10C7 | Mineral Lake | 44N | 4W | 15,16,17,18 |
| 10C9 | Blaise Dell Lake | 40N | 3W | 18 |
| | | 40N | 4W | 13,14,22,23 |
| 10C10 | Brunet River | 40N | 3W | 16,21,23 |
| 10C11 | Camp 4 Lake | 42N | 6W | 6 |
| | | 43N | 6W | 19,30,31 |
| 10T6 | Moose River | 42N | 3W | 31 |
| | | 42N | 4W | 35,36 |
| 10T7 | Christy Lake | 42N | 5W | 7,8,15,16,17 |
| 10T3 | Little Clam Lake | 42N | 4W | 5,8,17 |
| 10T9 | Woodtick Lake | 43N | 4W | 22,23,27,28,33 |
| 10T10 | Black Lake | 41N | 5W | 24,25,36 |

Table 5. Electric field intensities and magnetic flux densities[1] for revised Michigan transects.

| Site No. | Meas. Pt. | Meas. Yr. | Transverse E Field (Air) (V/M) | | Longitudinal E Field (Earth) (mV/M) | | Magnetic Flux Density (mG) | |
|---|---|---|---|---|---|---|---|---|
| | | | 76 Hz | 60 Hz | 76 Hz | 60 Hz | 76 Hz | 60 Hz |
| 10C1 | 2 | 84 | <0.001 | -- | 0.50 | 0.62 | 0.025 | 0.001 |
| 10C1 | 3 | 85 | <0.001 | -- | 1.0 | 0.27 | 0.025 | 0.003 |
| 10C2 | 1 | 84 | <0.001 | -- | 2.0 | 0.98 | 0.36 | 0.005 |
| 10C2 | 2 | 84 | <0.001 | -- | 1.0 | 0.35 | 0.028 | 0.003 |
| 10C5 | 2 | 84 | <0.001 | — | 0.50 | 0.35 | 0.009 | 0.008 |
| 10C5 | 3 | 84 | <0.001 | — | 0.50 | 0.11 | 0.008 | 0.001 |
| 10C12 | 1 | 85 | <0.001 | -- | 1.0 | 0.19 | 0.034 | 0.003 |
| 10C12 | 2 | 84 | <0.001 | -- | 1.0 | 0.62 | 0.025 | 0.001 |
| 10C13 | 1 | 85 | <0.001 | — | 1.0 | 0.34 | 0.040 | 0.007 |
| 10C13 | 2 | 85 | <0.001 | — | 1.0 | 0.14 | 0.036 | <0.001 |
| 10T1 | 1 | 84 | 0.05-0.5 | — | 48 | 0.08 | 2.5 | 0.006 |
| 10T1 | 2 | 84 | 0.05-0.5 | — | 48 | 0.08 | 2.5 | 0.006 |
| 10T2 | 1 | 84 | 0.05-0.5 | <0.001 | 48 | 0.42 | 2.5 | 0.002 |
| 10T2 | 2 | 84 | 0.05-0.5 | -- | 48 | 0.22 | 2.5 | <0.001 |
| 10T2 | 3 | 84 | 0.05-0.5 | <0.001 | 48 | 0.27 | 2.5 | <0.001 |
| 10T3 | 1 | 84 | 0.05-0.5 | — | 48 | 0.30 | 2.5 | <0.001 |
| 10T3 | 2 | 84 | 0.05-0.5 | — | 48 | 0.26 | 2.5 | <0.001 |
| 10T4 | 1 | 84 | 0.05-0.5 | — | 48 | 0.29 | 2.5 | <0.001 |
| 10T4 | 2 | 84 | 0.05-0.5 | — | 48 | 0.45 | 2.5 | <0.001 |
| 10T11 | 1 | 84 | 0.05-0.5 | — | 48 | 0.30 | 2.5 | <0.001 |
| 10T11 | 2 | 85 | 0.05-0.5 | — | 48 | 0.26 | 2.5 | <0.001 |

[1] Values shown are RMS magnitudes determined as the square root of the sum of the squares of the orthogonal field components measured. Data listed for 76 Hz is estimated based on analyses using the proposed location and operating conditions of the antenna elements along with the distance to each measurement point.

Table 6. Electric field intensities and magnetic flux densities[1,2] for revised Wisconsin transects.

| Site No. | Meas. Pt. | Meas. Yr. | Transverse E Field (Air) (V/M) | | Longitudinal E Field (Earth) (mV/M) | | Magnetic Flux Density (mG) | |
|---|---|---|---|---|---|---|---|---|
| | | | 76 Hz | 60 Hz | 76 Hz | 60 Hz | 76 Hz | 60 Hz |
| 10C6 | 1 | 84 | -- | -- | 2.70 | 0.06 | 0.021 | 0.001 |
| 10C6 | 2 | 84 | -- | -- | 3.50 | 0.10 | 0.026 | <0.001 |
| 10C7 | 2 | 84 | -- | -- | 0.90 | 0.05 | 0.010 | <0.001 |
| 10C7 | 3 | 85 | -- | -- | 0.61 | 0.074-0.093 | 0.016 | <0.001 |
| 10C9 | 1 | 84 | -- | -- | 1.60 | 0.10 | 0.047 | 0.001 |
| 10C9 | 2 | 84 | -- | -- | 2.52 | 0.01 | 0.037 | <0.001 |
| 10C10 | 1 | 84 | -- | -- | 2.52 | 0.02 | 0.031 | <0.001 |
| 10C10 | 2 | 84 | -- | -- | 0.61 | 0.03 | 0.015 | <0.001 |
| 10C11 | 1 | 85 | -- | -- | 1.26 | 0.23 | <0.001 | 0.002 |
| 10C11 | 2 | 85 | -- | -- | 1.89 | 0.038 | 0.009 | <0.001 |
| 10T6 | 1 | 84 | 0.201 | <0.001 | 136 | 0.04 | 3.64 | <0.001 |
| 10T6 | 2 | 84 | 0.121 | 0.014 | 99 | 0.02 | 7.57 | 0.001 |
| 10T7 | 1 | 84 | -- | -- | 200 | 0.04 | 4.76 | 0.001 |
| 10T7 | 2 | 84 | 0.170 | <0.001 | 153 | 0.10 | 2.36 | <0.001 |
| 10T7 | 3 | 84 | 0.195 | <0.001 | 179 | 0.10 | 4.99 | 0.001 |
| 10T3 | 2 | 84 | 0.102 | <0.001 | 117 | 0.05 | 5.40 | 0.001 |
| 10T3 | 3 | 85 | -- | -- | 163 | 0.10 | 10.0 | 0.003 |
| 10T3 | 4 | 85 | -- | -- | 72-76[2] | 0.032 | 6.6 | 0.002 |
| 10T9 | 2 | 84 | 0.474 | <0.001 | 463 | 0.13 | 1.5 | <0.001 |
| 10T9 | 3 | 85 | -- | -- | 88 | 0.036 | 4.1 | 0.002 |
| 10T10 | 1 | 84 | 0.101 | <0.001 | 83.5 | 0.04 | 4.56 | 0.001 |
| 10T10 | 2 | 84 | 0.201 | <0.001 | 156.5 | 0.09 | 4.98 | 0.001 |

[1] Values shown are RMS magnitudes determined as the square foot of the sum of the squares of the orthogonal field components measured.

[2] This includes only the contribution of the north/south antenna.

APPENDIX B

Summary data for census one and census two for the Rock Lake

and Christy Lake transects in Wisconsin.

Table 1. Summary of bird population data for census one and two for the Rock Lake-A transect in Wisconsin.

| Parameter | Census | | Mean |
|---|---|---|---|
| | 1 | 2 | |
| Downy Woodpecker | 1 | 0 | 0.5 |
| Olive-sided Flycatcher | 0 | 1 | 0.5 |
| Least Flycatcher | 2 | 0 | 1.0 |
| Great Crested Flycatcher | 2 | 0 | 1.0 |
| Blue Jay | 0 | 1 | 0.5 |
| Black-capped Chickadee | 1 | 1 | 1.0 |
| Red-breasted Nuthatch | 0 | 1 | 0.5 |
| White-breasted Nuthatch | 1 | 0 | 0.5 |
| Winter Wren | 1 | 2 | 1.5 |
| Hermit Thrush | 2 | 2 | 2.0 |
| American Robin | 0 | 1 | 0.5 |
| Red-eyed Vireo | 5 | 6 | 5.5 |
| Nashville Warbler | 3 | 6 | 4.5 |
| Northern Parula | 0 | 1 | 0.5 |
| Chestnut-sided Warbler | 0 | 3 | 1.5 |
| Black-throated Green Warbler | 5 | 4 | 4.5 |
| Blackburnian Warbler | 0 | 1 | 0.5 |
| Ovenbird | 7 | 10 | 8.5 |
| Mourning Warbler | 6 | 0 | 3.0 |
| Individuals | 31 | 35 | 33.0 |
| Species | 12 | 14 | |
| Total number of species | 19 | | |
| Number of species observed on both dates | 7 | | |
| Number of species observed on only census one | 5 | | |
| Number of species observed on only census two | 7 | | |

Table 2. Summary of bird population data for census one and two for the Rock Lake-B transect in Wisconsin.

| Parameter | Census | | Mean |
|---|---|---|---|
| | 1 | 2 | |
| Hairy Woodpecker | 1 | 0 | 0.5 |
| Least Flycatcher | 5 | 0 | 2.5 |
| Common Raven | 1 | 0 | 0.5 |
| Red-breasted Nuthatch | 0 | 2 | 1.0 |
| Winter Wren | 1 | 0 | 0.5 |
| Veery | 0 | 1 | 0.5 |
| American Robin | 0 | 1 | 0.5 |
| Red-eyed Vireo | 4 | 8 | 6.0 |
| Nashville Warbler | 1 | 4 | 2.5 |
| Northern Parula | 1 | 2 | 1.5 |
| Chestnut-sided Warbler | 0 | 2 | 1.0 |
| Black-throated Green Warbler | 4 | 5 | 4.5 |
| Ovenbird | 5 | 8 | 6.5 |
| Chipping Sparrow | 1 | 0 | 0.5 |
| White-throated Sparrow | 0 | 1 | 0.5 |
| Red Crossbill | 0 | 1 | 0.5 |
| Individuals | 26 | 35 | 30.5 |
| Species | 10 | 11 | |
| Total number of species | 16 | | |
| Number of species observed on both dates | 5 | | |
| Number of species observed on only census one | 5 | | |
| Number of species observed on both dates | 6 | | |

Table 3. Summary of bird population data for census one and two for the Rock Lake-C transect in Wisconsin.

| Parameter | Census | | Mean |
|---|---|---|---|
| | 1 | 2 | |
| Eastern Wood-Peewee | 1 | 0 | 0.5 |
| Least Flycatcher | 14 | 3 | 8.5 |
| Great Crested Flycatcher | 3 | 0 | 1.5 |
| Blue Jay | 1 | 0 | 0.5 |
| Black-capped Chickadee | 1 | 0 | 0.5 |
| Red-breasted Nuthatch | 2 | 0 | 1.0 |
| Winter Wren | 0 | 1 | 0.5 |
| Veery | 0 | 1 | 0.5 |
| Hermit Thrush | 1 | 1 | 1.0 |
| American Robin | 0 | 3 | 1.5 |
| Red-eyed Vireo | 6 | 6 | 6.0 |
| Nashville Warbler | 0 | 3 | 1.5 |
| Northern Parula | 0 | 4 | 2.0 |
| Chestnut-sided Warbler | 2 | 1 | 1.5 |
| Black-throated Green Warbler | 7 | 1 | 4.0 |
| Black-and-white Warbler | 1 | 0 | 0.5 |
| Ovenbird | 7 | 6 | 6.5 |
| Mourning Warbler | 1 | 0 | 0.5 |
| Canada Warbler | 0 | 1 | 0.5 |
| Scarlet Tanager | 0 | 1 | 0.5 |
| American Goldfinch | 0 | 1 | 0.5 |
| Individuals | 47 | 33 | 40.0 |
| Species | 14 | 14 | |
| Total number of species | 21 | | |
| Number of species observed on both dates | 6 | | |
| Number of species observed on only census one | 7 | | |
| Number of species observed on only census two | 8 | | |

Table 4. Summary of bird population data for census one and two for the Rock Lake-D transect in Wisconsin.

| Parameter | Census | | Mean |
|---|---|---|---|
| | 1 | 2 | |
| Ruffed Grouse | 2 | 0 | 1.0 |
| Hairy Woodpecker | 1 | 0 | 0.5 |
| Eastern Wood-Peewee | 1 | 0 | 0.5 |
| Least Flycatcher | 4 | 4 | 4.0 |
| Great Crested Flycatcher | 3 | 0 | 1.5 |
| Blue Jay | 1 | 0 | 0.5 |
| Hermit Thrush | 2 | 0 | 1.0 |
| Solitary Vireo | 0 | 1 | 0.5 |
| Red-eyed Vireo | 13 | 6 | 9.5 |
| Nashville Warbler | 2 | 5 | 3.5 |
| Northern Parula | 1 | 1 | 1.0 |
| Chestnut-sided Warbler | 1 | 3 | 2.0 |
| Black-throated Green Warbler | 7 | 5 | 6.0 |
| Black-and-white Warbler | 2 | 2 | 2.0 |
| Ovenbird | 10 | 6 | 8.0 |
| Mourning Warbler | 3 | 0 | 1.5 |
| Common Yellowthroat | 0 | 1 | 0.5 |
| Red Crossbill | 0 | 1 | 0.5 |
| Individuals | 53 | 35 | 44.0 |
| Species | 15 | 11 | |
| Total number of species | 18 | | |
| Number of species observed on both dates | 8 | | |
| Number of species observed on only census one | 7 | | |
| Number of species observed on only census two | 3 | | |

Table 5. Summary of bird population data for census one and two for the Rock Lake-E transect in Wisconsin.

| Parameter | Census | | Mean |
|---|---|---|---|
| | 1 | 2 | |
| Broad-winged Hawk | 0 | 1 | 0.5 |
| Ruffed Grouse | 3 | 0 | 1.5 |
| Downy Woodpecker | 1 | 0 | 0.5 |
| Eastern Wood-Peewee | 2 | 0 | 1.0 |
| Least Flycatcher | 7 | 4 | 5.5 |
| Great Crested Flycatcher | 3 | 3 | 3.0 |
| Blue Jay | 2 | 1 | 1.5 |
| Black-capped Chickadee | 0 | 1 | 0.5 |
| Red-breasted Nuthatch | 1 | 0 | 0.5 |
| Winter Wren | 0 | 1 | 0.5 |
| Veery | 1 | 0 | 0.5 |
| Hermit Thrush | 0 | 2 | 1.0 |
| American Robin | 0 | 1 | 0.5 |
| Red-eyed Vireo | 8 | 6 | 7.0 |
| Golden-winged Warbler | 1 | 0 | 0.5 |
| Nashville Warbler | 2 | 1 | 1.5 |
| Northern Parula | 1 | 1 | 1.0 |
| Chestnut-sided Warbler | 0 | 4 | 2.0 |
| Black-throated Green Warbler | 3 | 7 | 5.0 |
| Black-and-white Warbler | 3 | 1 | 2.0 |
| Ovenbird | 6 | 6 | 6.0 |
| Mourning Warbler | 2 | 0 | 1.0 |
| Canada Warbler | 1 | 0 | 0.5 |
| White-throated Sparrow | 0 | 4 | 2.0 |
| Red-winged Blackbird | 1 | 0 | 0.5 |
| Red Crossbill | 1 | 0 | 0.5 |
| Individuals | 49 | 44 | 46.5 |
| Species | 19 | 16 | |
| Total number of species | 26 | | |
| Number of species observed on both dates | 9 | | |
| Number of species observed on only census one | 10 | | |
| Number of species observed on only census two | 7 | | |

Table 6. Summary of bird population data for census one and two
for the Rock Lake-F transect in Wisconsin.

| Parameter | Census | | Mean |
|---|---|---|---|
| | 1 | 2 | |
| Ruffed Grouse | 3 | 0 | 1.5 |
| Northern Flicker | 1 | 0 | 0.5 |
| Alder Flycatcher | 2 | 1 | 1.5 |
| Least Flycatcher | 1 | 4 | 2.0 |
| Great Crested Flycatcher | 2 | 2 | 2.0 |
| Common Raven | 1 | 0 | 0.5 |
| Black-capped Chickadee | 1 | 1 | 1.0 |
| Red-breasted Nuthatch | 0 | 1 | 0.5 |
| White-breasted Nuthatch | 1 | 0 | 0.5 |
| Winter Wren | 1 | 1 | 1.0 |
| Hermit Thrush | 1 | 2 | 1.5 |
| Solitary Vireo | 0 | 1 | 0.5 |
| Red-eyed Vireo | 6 | 3 | 4.5 |
| Golden-winged Warbler | 1 | 0 | 0.5 |
| Nashville Warbler | 2 | 4 | 3.0 |
| Northern Parula | 1 | 2 | 1.5 |
| Yellow Warbler | 0 | 2 | 1.0 |
| Chestnut-sided Warbler | 0 | 4 | 2.0 |
| Magnolia Warbler | 1 | 0 | 0.5 |
| Black-throated Green Warbler | 5 | 2 | 3.5 |
| Black-and-white Warbler | 1 | 1 | 1.0 |
| American Redstart | 1 | 0 | 0.5 |
| Ovenbird | 10 | 6 | 8.0 |
| Common Yellowthroat | 2 | 0 | 1.0 |
| Canada Warbler | 1 | 0 | 0.5 |
| Chipping Sparrow | 2 | 1 | 1.5 |
| White-throated Sparrow | 0 | 1 | 0.5 |
| Individuals | 47 | 39 | 43.0 |
| Species | 22 | 18 | |
| Total number of species | 27 | | |
| Number of species observed on both dates | 13 | | |
| Number of species observed on only census one | 9 | | |
| Number of species observed on only census two | 5 | | |

Table 7. Summary of bird population data for census one and two for the Rock Lake-G transect in Wisconsin.

| Parameter | Census | | Mean |
|---|---|---|---|
| | 1 | 2 | |
| Broad-winged Hawk | 1 | 0 | 0.5 |
| Ruffed Grouse | 2 | 0 | 1.0 |
| Hairy Woodpecker | 0 | 1 | 0.5 |
| Olive-sided Flycatcher | 1 | 1 | 1.0 |
| Least Flycatcher | 1 | 0 | 0.5 |
| Great Crested Flycatcher | 3 | 1 | 2.0 |
| Blue Jay | 1 | 1 | 1.0 |
| Black-capped Chickadee | 1 | 0 | 0.5 |
| Winter Wren | 2 | 3 | 2.5 |
| Hermit Thrush | 1 | 2. | 1.5 |
| American Robin | 0 | 2 | 1.0 |
| Solitary Vireo | 1 | 0 | 0.5 |
| Red-eyed Vireo | 4 | 9 | 6.5 |
| Golden-winged Warbler | 1 | 0 | 0.5 |
| Nashville Warbler | 4 | 5 | 4.5 |
| Northern Parula | 0 | 1 | 0.5 |
| Cape May Warbler | 1 | 2 | 1.5 |
| Yellow-rumped Warbler | 3 | 0 | 1.5 |
| Black-throated Green Warbler | 2 | 5 | 3.5 |
| Palm Warbler | 1 | 0 | 0.5 |
| Black-and-white Warbler | 3 | 1 | 2.0 |
| Ovenbird | 5 | 10 | 7.5 |
| Connecticut Warbler | 1 | 0 | 0.5 |
| Canada Warbler | 1 | 0 | 0.5 |
| Chipping Sparrow | 0 | 1 | 0.5 |
| White-throated Sparrow | 0 | 1 | 0.5 |
| Individuals | 40 | 47 | 43.5 |
| Species | 21 | 16 | |
| Total number of species | 25 | | |
| Number of species observed on both dates | 11 | | |
| Number of species observed on only census one | 10 | | |
| Number of species observed on only census two | 5 | | |

Table 9. Summary of bird population data for census one and two
for the Rock Lake-H transect in Wisconsin.

| Parameter | Census | | Mean |
|---|---|---|---|
| | 1 | 2 | |
| Ruffed Grouse | 2 | 0 | 1.0 |
| Downy Woodpecker | 1 | 0 | 0.5 |
| Hairy Woodpecker | 0 | 1 | 0.5 |
| Pileated Woodpecker | 1 | 1 | 1.0 |
| Eastern Wood-Peewee | 0 | 1 | 0.5 |
| Least Flycatcher | 3 | 3 | 3.0 |
| Great Crested Flycatcher | 3 | 1 | 2.0 |
| Blue Jay | 1 | 0 | 0.5 |
| American Crow | 0 | 1 | 0.5 |
| White-breasted Nuthatch | 1 | 0 | 0.5 |
| Winter Wren | 2 | 0 | 1.0 |
| Veery | 1 | 0 | 0.5 |
| American Robin | 0 | 3 | 1.5 |
| Red-eyed Vireo | 8 | 5 | 6.5 |
| Nashville Warbler | 3 | 2 | 2.5 |
| Yellow Warbler | 0 | 3 | 1.5 |
| Chestnut-sided Warbler | 1 | 3 | 2.0 |
| Magnolia Warbler | 1 | 0 | 0.5 |
| Black-throated Green Warbler | 6 | 6 | 6.0 |
| Black-and-white Warbler | 1 | 1 | 1.0 |
| American Redstart | 1 | 0 | 0.5 |
| Ovenbird | 11 | 12 | 11.5 |
| Canada Warbler | 1 | 0 | 0.5 |
| Rose-breasted Grosbeak | 0 | 1 | 0.5 |
| Individuals | 49 | 41 | 44.5 |
| Species | 18 | 15 | |
| Total number of species | 24 | | |
| Number of species observed on both dates | 9 | | |
| Number of species observed on only census one | 9 | | |
| Number of species observed on only census two | 6 | | |
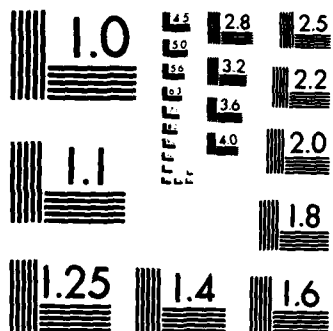
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Table 9.  Summary of bird population data for census one and two
for the Christy Lake-A transect in Wisconsin.

| Parameter | Census | | Mean |
|---|---|---|---|
| | 1 | 2 | |
| Black-billed Cuckoo | 1 | 0 | 0.5 |
| Yellow-bellied Flycatcher | 1 | 3 | 2.0 |
| Blue Jay | 0 | 1 | 0.5 |
| Black-capped Chickadee | 1 | 0 | 0.5 |
| Golden-crowned Kinglet | 0 | 1 | 0.5 |
| Ruby-crowned Kinglet | 2 | 1 | 1.5 |
| Hermit Thrush | 0 | 3 | 1.5 |
| American Robin | 1 | 0 | 0.5 |
| Solitary Vireo | 1 | 0 | 0.5 |
| Nashville Warbler | 12 | 9 | 10.5 |
| Magnolia Warbler | 0 | 1 | 0.5 |
| Yellow-rumped Warbler | 1 | 2 | 1.5 |
| Black-throated Green Warbler | 1 | 1 | 1.0 |
| Palm Warbler | 1 | 0 | 0.5 |
| Black-and-white Warbler | 1 | 0 | 0.5 |
| Ovenbird | 2 | 5 | 3.5 |
| Mourning Warbler | 0 | 1 | 0.5 |
| Common Yellowthroat | 2 | 1 | 1.5 |
| White-throated Sparrow | 2 | 4 | 3.0 |
| Individuals | 29 | 33 | 31.0 |
| Species | 14 | 13 | |
| Total number of species | 19 | | |
| Number of species observed on both dates | 8 | | |
| Number of species observed on only census one | 6 | | |
| Number of species observed on only census two | 5 | | |

Table 10. Summary of bird population data for census one and two
for the Christy Lake-B transect in Wisconsin.

| Parameter | Census | | Mean |
|---|---|---|---|
| | 1 | 2 | |
| Northern Flicker | 0 | 1 | 0.5 |
| Yellow-bellied Flycatcher | 3 | 3 | 3.0 |
| Blue Jay | 1 | 0 | 0.5 |
| Red-breasted Nuthatch | 0 | 1 | 0.5 |
| Hermit Thrush | 1 | 1 | 1.0 |
| American Robin | 1 | 0 | 0.5 |
| Red-eyed Vireo | 2 | 0 | 1.0 |
| Nashville Warbler | 11 | 11 | 11.0 |
| Cape May Warbler | 0 | 2 | 1.0 |
| Yellow-rumped Warbler | 3 | 2 | 2.5 |
| Palm Warbler | 2 | 0 | 1.0 |
| Black-and-white Warbler | 2 | 0 | 1.0 |
| American Redstart | 0 | 1 | 0.5 |
| Ovenbird | 3 | 3 | 3.0 |
| Connecticut Warbler | 1 | 5 | 3.0 |
| Mourning Warbler | 1 | 0 | 0.5 |
| Scarlet Tanager | 0 | 1 | 0.5 |
| Chipping Sparrow | 1 | 0 | 0.5 |
| Lincoln's Sparrow | 3 | 0 | 1.5 |
| White-throated Sparrow | 3 | 4 | 3.5 |
| Individuals | 38 | 35 | 36.5 |
| Soecies | 15 | 12 | |
| Total number of species | 20 | | |
| Number of species observed on both dates | 7 | | |
| Number of species observed on only census one | 3 | | |
| Number of species observed on only census two | 5 | | |

Table 11. Summary of bird population data for census one and two
for the Christy Lake-C transect in Wisconsin.

| Parameter | Census | | Mean |
|---|---|---|---|
| | 1 | 2 | |
| Yellow-bellied Flycatcher | 2 | 3 | 2.5 |
| Black-capped Chickadee | 2 | 0 | 1.0 |
| Boreal Chickadee | 1 | 0 | 0.5 |
| Red-breasted Nuthatch | 2 | 0 | 1.0 |
| American Robin | 1 | 0 | 0.5 |
| Solitary Vireo | 1 | 0 | 0.5 |
| Red-eyed Vireo | 2 | 3 | 2.5 |
| Nashville Warbler | 12 | 9 | 10.5 |
| Chestnut-sided Warbler | 0 | 1 | 0.5 |
| Cape May Warbler | 0 | 1 | 0.5 |
| Yellow-rumped Warbler | 2 | 0 | 1.0 |
| Black-throated Green Warbler | 0 | 1 | 0.5 |
| Palm Warbler | 0 | 2 | 1.0 |
| Black-and-white Warbler | 1 | 0 | 0.5 |
| American Redstart | 0 | 1 | 0.5 |
| Ovenbird | 2 | 0 | 1.0 |
| Connecticut Warbler | 4 | 3 | 3.5 |
| Common Yellowthroat | 1 | 0 | 0.5 |
| Scarlet Tanager | 0 | 1 | 0.5 |
| Rose-breasted Grosbeak | 1 | 0 | 0.5 |
| Indigo Bunting | 0 | 1 | 0.5 |
| Chipping Sparrow | 1 | 0 | 0.5 |
| Song Sparrow | 2 | 1 | 1.5 |
| Lincoln's Sparrow | 2 | 2 | 2.0 |
| White-throated Sparrow | 7 | 5 | 6.0 |
| Brown-headed Cowbird | 1 | 0 | 0.5 |
| Individuals | 47 | 34 | 40.5 |
| Species | 19 | 14 | |
| Total number of species | 26 | | |
| Number of species observed on both dates | 7 | | |
| Number of species observed on only census one | 12 | | |
| Number of species observed on only census two | 7 | | |

Table 12. Summary of bird population data for census one and two for the Christy Lake-D transect in Wisconsin.

| Parameter | Census | | Mean |
|---|---|---|---|
| | 1 | 2 | |
| Yellow-bellied Flycatcher | 0 | 3 | 1.5 |
| Blue Jay | 1 | 2 | 1.5 |
| Black-capped Chickadee | 1 | 0 | 0.5 |
| Winter Wren | 1 | 0 | 0.5 |
| Hermit Thrush | 0 | 2 | 1.0 |
| American Robin | 2 | 0 | 1.0 |
| Brown Thrasher | 1 | 0 | 0.5 |
| Red-eyed Vireo | 2 | 2 | 2.0 |
| Nashville Warbler | 7 | 7 | 7.0 |
| Northern Parula | 1 | 0 | 0.5 |
| Chestnut-sided Warbler | 1 | 1 | 1.0 |
| Cape May Warbler | 0 | 2 | 1.0 |
| Black-throated Blue Warbler | 0 | 2 | 1.0 |
| Yellow-rumped Warbler | 1 | 2 | 1.5 |
| Black-throated Green Warbler | 2 | 1 | 1.5 |
| Black-and-white Warbler | 2 | 0 | 1.0 |
| Ovenbird | 7 | 4 | 5.5 |
| Mourning Warbler | 0 | 2 | 1.0 |
| Common Yellowthroat | 1 | 0 | 0.5 |
| Scarlet Tanager | 0 | 2 | 1.0 |
| Rose-breasted Grosbeak | 2 | 0 | 1.0 |
| White-throated Sparrow | 3 | 1 | 2.0 |
| Individuals | 36 | 33 | 34.5 |
| Species | 16 | 14 | |
| Total number of species | 22 | | |
| Number of species observed on both dates | 8 | | |
| Number of species observed on only census one | 8 | | |
| Number of species observed on only census two | 6 | | |

Table 13. Summary of bird population data for census one and two for the Christy Lake-E transect in Wisconsin.

| Parameter | Census | | Mean |
|---|---|---|---|
| | 1 | 2 | |
| Ruffed Grouse | 0 | 1 | 0.5 |
| Common Snipe | 1 | 0 | 0.5 |
| Yellow-bellied Flycatcher | 0 | 2 | 1.0 |
| Alder Flycatcher | 0 | 1 | 0.5 |
| Least Flycatcher | 3 | 0 | 1.5 |
| Eastern Kingbird | 1 | 0 | 0.5 |
| Blue Jay | 3 | 0 | 1.5 |
| Black-capped Chickadee | 3 | 1 | 2.0 |
| Sedge Wren | 7 | 1 | 4.0 |
| Golden-crowned Kinglet | 0 | 1 | 0.5 |
| Veery | 0 | 3 | 1.5 |
| American Robin | 0 | 1 | 0.5 |
| Red-eyed Vireo | 0 | 1 | 0.5 |
| Nashville Warbler | 19 | 13 | 16.0 |
| Black-and-white Warbler | 1 | 0 | 0.5 |
| Ovenbird | 3 | 0 | 1.5 |
| Common Yellowthroat | 2 | 6 | 4.0 |
| Scarlet Tanager | 0 | 1 | 0.5 |
| Rose-breasted Grosbeak | 3 | 0 | 1.5 |
| Swamp Sparrow | 2 | 3 | 2.5 |
| White-throated Sparrow | 3 | 3 | 3.0 |
| Individuals | 56 | 38 | 47.0 |
| Species | 13 | 14 | |
| Total number of species | 21 | | |
| Number of species observed on both dates | 6 | | |
| Number of species observed on only census one | 7 | | |
| Number of species observed on only census two | 8 | | |

Table 14. Summary of bird population data for census one and two for the Christy Lake-F transect in Wisconsin.

| Parameter | Census | | Mean |
|---|---|---|---|
| | 1 | 2 | |
| Common Snipe | 1 | 0 | 0.5 |
| Yellow-bellied Flycatcher | 0 | 1 | 0.5 |
| Great Crested Flycatcher | 1 | 0 | 0.5 |
| Black-capped Chickadee | 0 | 5 | 2.5 |
| Red-eyed Vireo | 5 | 1 | 3.0 |
| Nashville Warbler | 7 | 6 | 6.5 |
| Cape May Warbler | 0 | 1 | 0.5 |
| Yellow-rumped Warbler | 3 | 1 | 2.0 |
| Black-and-white Warbler | 2 | 0 | 1.0 |
| Ovenbird | 9 | 7 | 8.0 |
| Mourning Warbler | 2 | 5 | 3.5 |
| Chipping Sparrow | 1 | 1 | 1.0 |
| White-throated Sparrow | 1 | 1 | 1.0 |
| Evening Grosbeak | 0 | 1 | 0.5 |
| Individuals | 32 | 30 | 31.0 |
| Species | 10 | 11 | |
| Total number of species | 14 | | |
| Number of species observed on both dates | 7 | | |
| Number of species observed on only one date | 3 | | |
| Number of species observed on only census two | 4 | | |

Table 15. Summary of bird population data for census one and two for the Christy Lake-G transect in Wisconsin.

| Parameter | Census | | Mean |
|---|---|---|---|
| | 1 | 2 | |
| Blue Jay | 5 | 0 | 2.5 |
| Red-eyed Vireo | 7 | 3 | 5.0 |
| Nashville Warbler | 10 | 1 | 5.5 |
| Chestnut-sided Warbler | 2 | 0 | 1.0 |
| Yellow-rumped Warbler | 4 | 0 | 2.0 |
| Black-throated Green Warbler | 2 | 2 | 2.0 |
| American Redstart | 0 | 2 | 1.0 |
| Ovenbird | 12 | 8 | 10.0 |
| Mourning Warbler | 3 | 5 | 4.0 |
| Common Yellowthroat | 0 | 1 | 0.5 |
| Song Sparrow | 0 | 2 | 1.0 |
| White-throated Sparrow | 0 | 2 | 1.0 |
| Individuals | 45 | 26 | 35.5 |
| Species | 8 | 9 | |
| Total number of species | 12 | | |
| Number of species observed on both dates | 5 | | |
| Number of species observed on only census one | 3 | | |
| Number of species observed on only census two | 4 | | |

Table 16. Summary of bird population data for census one and two for the Christy Lake-H transect in Wisconsin.

| Parameter | Census | | Mean |
|---|---|---|---|
| | 1 | 2 | |
| Yellow-bellied Flycatcher | 0 | 1 | 0.5 |
| Alder Flycatcher | 2 | 4 | 3.0 |
| Red-breasted Nuthatch | 0 | 1 | 0.5 |
| Solitary Vireo | 0 | 1 | 0.5 |
| Red-eyed Vireo | 2 | 1 | 1.5 |
| Nashville Warbler | 6 | 7 | 6.5 |
| Northern Parula | 1 | 0 | 0.5 |
| Chestnut-sided Warbler | 9 | 5 | 7.0 |
| Black-and-white Warbler | 1 | 0 | 0.5 |
| Ovenbird | 0 | 1 | 0.5 |
| Mourning Warbler | 2 | 1 | 1.5 |
| Common Yellowthroat | 1 | 0 | 0.5 |
| Song Sparrow | 4 | 1 | 2.5 |
| Swamp Sparrow | 0 | 1 | 0.5 |
| White-throated Sparrow | 2 | 4 | 3.0 |
| American Goldfinch | 1 | 1 | 1.0 |
| Individuals | 31 | 29 | 30.0 |
| Species | 11 | 13 | |
| Total number of species | 16 | | |
| Number of species observed on both dates | 8 | | |
| Number of species observed on only census one | 3 | | |
| Number of species observed on only census two | 5 | | |

# APPENCIX C

Summary data for census one and census two for the Leeman's Road
and Lost Lake transects in Michigan.

Table 1. Summary of bird population data for census one and two for the Lost Lake-A transect in Michigan.

| Parameter | Census | | Mean |
|---|---|---|---|
| | 1 | 2 | |
| Least Flycatcher | 1 | 1 | 1.0 |
| White-breasted Nuthatch | 1 | 0 | 0.5 |
| Veery | 1 | 0 | 0.5 |
| Red-eyed Vireo | 12 | 10 | 11.0 |
| Black-throated Green Warbler | 3 | 5 | 4.0 |
| Ovenbird | 12 | 13 | 12.5 |
| Scarlet Tanager | 1 | 1 | 1.0 |
| Rose-breasted Grosbeak | 2 | 0 | 1.0 |
| Indigo Bunting | 1 | 1 | 1.0 |
| Individuals | 32 | 33 | 32.5 |
| Species | 7 | 8 | |
| Total number of species | 9 | | |
| Number of species observed on both dates | 6 | | |
| Number of species observed on only census one | 3 | | |
| Number of species observed on only census two | 0 | | |

Table 2.   Summary of bird population data for census one and two
for the Lost Lake-B transect in Michigan.

| Parameter | Census | | Mean |
|---|---|---|---|
| | 1 | 2 | |
| American Woodcock | 1 | 0 | 0.5 |
| Downy Woodpecker | 1 | 0 | 0.5 |
| Eastern Wood-Peewee | 0 | 1 | 0.5 |
| Yellow-bellied Flycatcher | 0 | 1 | 0.5 |
| Black-capped Chickadee | 3 | 0 | 1.5 |
| Hermit Thrush | 0 | 1 | 0.5 |
| American Robin | 0 | 1 | 0.5 |
| Red-eyed Vireo | 7 | 6 | 6.5 |
| Nashville Warbler | 4 | 6 | 5.0 |
| Cape May Warbler | 1 | 1 | 1.0 |
| Black-throated Green Warbler | 3 | 2 | 2.5 |
| Black-and-white Warbler | 2 | 0 | 1.0 |
| Ovenbird | 7 | 6 | 6.5 |
| Scarlet Tanager | 1 | 1 | 1.0 |
| Rose-breasted Grosbeak | 4 | 2 | 3.0 |
| White-throated Sparrow | 2 | 3 | 2.5 |
| Individuals | 38 | 29 | 33.5 |
| Species | 12 | 12 | |
| Total number of species | 16 | | |
| Number of species observed on both dates | 8 | | |
| Number of species observed on only census one | 4 | | |
| Number of species observed on only census two | 4 | | |

Table 3. Summary of bird population data for census one and two for the Lost Lake-C transect in Michigan.

| Parameter | Census | | Mean |
|---|---|---|---|
| | 1 | 2 | |
| Red-tailed Hawk | 1 | 1 | 1.0 |
| Yellow-bellied Sapsucker | 2 | 0 | 1.0 |
| Hairy Woodpecker | 0 | 1 | 0.5 |
| Northern Flicker | 2 | 0 | 1.0 |
| Yellow-bellied Flycatcher | 1 | 0 | 0.5 |
| Least Flycatcher | 1 | 4 | 2.5 |
| Great Crested Flycatcher | 2 | 2 | 2.0 |
| Blue Jay | 1 | 0 | 0.5 |
| Black-capped Chickadee | 5 | 2 | 3.5 |
| Red-breasted Nuthatch | 0 | 1 | 0.5 |
| White-breasted Nuthatch | 0 | 1 | 0.5 |
| Winter Wren | 2 | 2 | 2.0 |
| Veery | 1 | 0 | 0.5 |
| Hermit Thrush | 5 | 3 | 4.0 |
| American Robin | 1 | 0 | 0.5 |
| Red-eyed Vireo | 0 | 3 | 1.5 |
| Nashville Warbler | 1 | 6 | 3.5 |
| Yellow-rumped Warbler | 1 | 0 | 0.5 |
| Black-throated Green Warbler | 0 | 5 | 2.5 |
| Black-and-white Warbler | 3 | 0 | 1.5 |
| Ovenbird | 7 | 8 | 7.5 |
| Mourning Warbler | 0 | 1 | 0.5 |
| Common Yellowthroat | 1 | 0 | 0.5 |
| Rose-breasted Grosbeak | 0 | 2 | 1.0 |
| Individuals | 37 | 42 | 39.5 |
| Species | 17 | 15 | |
| Total number of species | 24 | | |
| Number of species observed on both dates | 8 | | |
| Number of species observed on only census one | 9 | | |
| Number of species observed on only census two | 7 | | |

Table 4.  Summary of bird population data for census one and two for the Lost Lake-D transect in Michigan.

| Parameter | Census | | Mean |
|---|---|---|---|
| | 1 | 2 | |
| Downy Woodpecker | 1 | 0 | 0.5 |
| Least Flycatcher | 0 | 3 | 1.5 |
| Great Crested Flycatcher | 4 | 1 | 2.5 |
| Blue Jay | 5 | 1 | 3.0 |
| Veery | 2 | 0 | 1.0 |
| Cedar Waxwing | 1 | 0 | 0.5 |
| Red-eyed Vireo | 1 | 5 | 3.0 |
| Golden-winged Warbler | 1 | 0 | 0.5 |
| Nashville Warbler | 4 | 5 | 4.5 |
| Northern Parula | 0 | 1 | 0.5 |
| Black-throated Green Warbler | 1 | 5 | 3.0 |
| Black-and-white Warbler | 4 | 0 | 2.0 |
| Ovenbird | 6 | 2 | 4.0 |
| Northern Waterthrush | 1 | 1 | 1.0 |
| Mourning Warbler | 0 | 1 | 0.5 |
| Common Yellowthroat | 3 | 6 | 4.5 |
| Rose-breasted Grosbeak | 2 | 4 | 3.0 |
| White-throated Sparrow | 4 | 5 | 4.5 |
| Brown-headed Cowbird | 1 | 0 | 0.5 |
| Individuals | 42 | 40 | 41.0 |
| Species | 16 | 13 | |
| Total number of species | 19 | | |
| Number of species observed on both dates | 10 | | |
| Number of species observed on only census one | 6 | | |
| Number of species observed on only census two | 3 | | |

Table 5. Summary of bird population data for census one and two for the Lost Lake-E transect in Michigan.

| Parameter | Census | | Mean |
|---|---|---|---|
| | 1 | 2 | |
| Yellow-bellied Sapsucker | 1 | 1 | 1.0 |
| Downy Woodpecker | 1 | 0 | 0.5 |
| Yellow-bellied Flycatcher | 1 | 0 | 0.5 |
| Least Flycatcher | 2 | 3 | 2.5 |
| Great Crested Flycatcher | 2 | 2 | 2.0 |
| Blue Jay | 1 | 1 | 1.0 |
| Northern Raven | 1 | 0 | 0.5 |
| Black-capped Chickadee | 2 | 1 | 1.5 |
| Red-breasted Nuthatch | 1 | 0 | 0.5 |
| Veery | 2 | 0 | 1.0 |
| Hermit Thrush | 0 | 1 | 0.5 |
| American Robin | 0 | 1 | 0.5 |
| Red-eyed Vireo | 2 | 4 | 3.0 |
| Nashville Warbler | 4 | 1 | 2.5 |
| Northern Parula | 0 | 1 | 0.5 |
| Chestnut-sided Warbler | 0 | 2 | 1.0 |
| Black-throated Green Warbler | 1 | 1 | 1.0 |
| Black-and-white Warbler | 1 | 0 | 0.5 |
| Ovenbird | 8 | 8 | 8.0 |
| Northern Waterthrush | 2 | 0 | 1.0 |
| Common Yellowthroat | 1 | 1 | 1.0 |
| Rose-breasted Grosbeak | 0 | 2 | 1.0 |
| White-throated Sparrow | 3 | 5 | 4.0 |
| Purple Finch | 2 | 1 | 1.5 |
| Individuals | 38 | 36 | 37.0 |
| Species | 19 | 17 | |
| Total number of species | 24 | | |
| Number of species observed on both dates | 12 | | |
| Number of species observed on only census one | 7 | | |
| Number of species observed on only census two | 5 | | |

Table 6. Summary of bird population data for census one and two
for the Lost Lake-F transect in Michigan.

| Parameter | Census | | Mean |
|---|---|---|---|
| | 1 | 2 | |
| Downy Woodpecker | 0 | 1 | 0.5 |
| Northern Flicker | 1 | 2 | 1.5 |
| Great Crested Flycatcher | 1 | 0 | 0.5 |
| Blue Jay | 3 | 1 | 2.0 |
| Red-breasted Nuthatch | 1 | 0 | 0.5 |
| Winter Wren | 2 | 1 | 1.5 |
| American Robin | 1 | 0 | 0.5 |
| Golden-winged Warbler | 0 | 2 | 1.0 |
| Northern Parula | 1 | 0 | 0.5 |
| Chestnut-sided Warbler | 5 | 6 | 5.5 |
| Pine Warbler | 1 | 0 | 0.5 |
| Black-and-white Warbler | 1 | 0 | 0.5 |
| Ovenbird | 2 | 0 | 1.0 |
| Mourning Warbler | 3 | 10 | 6.5 |
| Common Yellowthroat | 0 | 1 | 0.5 |
| Rose-breasted Grosbeak | 0 | 3 | 1.5 |
| Indigo Bunting | 1 | 3 | 2.0 |
| White-throated Sparrow | 7 | 8 | 7.5 |
| Red-winged Blackbird | 0 | 1 | 0.5 |
| Individuals | 30 | 39 | 34.5 |
| Species | 14 | 12 | |
| Total number of species | 19 | | |
| Number of species observed on both dates | 7 | | |
| Number of species observed on only census one | 7 | | |
| Number of species observed on only census two | 5 | | |

Table 7.  Summary of bird population data for census one and two
for the Lost Lake-G transect in Michigan.

| Parameter | Census | | Mean |
|---|---|---|---|
| | 1 | 2 | |
| Yellow-bellied Sapsucker | 1 | 0 | 0.5 |
| Northern Flicker | 1 | 0 | 0.5 |
| Least Flycatcher | 1 | 4 | 2.5 |
| Blue Jay | 1 | 0 | 0.5 |
| White-breasted Nuthatch | 0 | 1 | 0.5 |
| Veery | 1 | 1 | 1.0 |
| Hermit Thrush | 0 | 1 | 0.5 |
| Cedar Waxwing | 1 | 0 | 0.5 |
| Red-eyed Vireo | 3 | 3 | 3.0 |
| Chestnut-sided Warbler | 1 | 5 | 3.0 |
| Black-throated Green Warbler | 0 | 2 | 1.0 |
| Ovenbird | 5 | 5 | 5.0 |
| Common Yellowthroat | 5 | 5 | 5.0 |
| Rose-breasted Grosbeak | 1 | 0 | 0.5 |
| Indigo Bunting | 1 | 1 | 1.0 |
| Song Sparrow | 2 | 0 | 1.0 |
| Swamp Sparrow | 2 | 0 | 1.0 |
| Red-winged Blackbird | 8 | 2 | 5.0 |
| Purple Finch | 1 | 0 | 0.5 |
| Unidentified Woodpecker | 1 | 0 | 0.5 |
| Individuals | 35 | 30 | 32.5 |
| Species | 16 | 11 | |
| Total number of species | 19 | | |
| Number of species observed on both dates | 9 | | |
| Number of species observed on only census one | 9 | | |
| Number of species observed on only census two | 3 | | |

Table 8. Summary of bird population data for census one and two
for the Lost Lake-H transect in Michigan.

| Parameter | Census | | Mean |
|---|---|---|---|
| | 1 | 2 | |
| American Woodcock | 1 | 1 | 1.0 |
| Yellow-bellied Sapsucker | 0 | 2 | 1.0 |
| Northern Flicker | 0 | 1 | 0.5 |
| Great Crested Flycatcher | 0 | 1 | 0.5 |
| Blue Jay | 0 | 1 | 0.5 |
| Black-capped Chickadee | 0 | 2 | 1.0 |
| Red-breasted Nuthatch | 1 | 1 | 1.0 |
| Veery | 1 | 1 | 1.0 |
| Hermit Thrush | 0 | 1 | 0.5 |
| American Robin | 2 | 0 | 1.0 |
| Red-eyed Vireo | 2 | 5 | 3.5 |
| Golden-winged Warbler | 1 | 0 | 0.5 |
| Yellow Warbler | 2 | 0 | 1.0 |
| Chestnut-sided Warbler | 1 | 2 | 1.5 |
| Black-throated Green Warbler | 2 | 0 | 1.0 |
| Black-and-white Warbler | 1 | 1 | 1.0 |
| American Redstart | 1 | 0 | 0.5 |
| Ovenbird | 1 | 2 | 1.5 |
| Mourning Warbler | 1 | 1 | 1.0 |
| Common Yellowthroat | 3 | 3 | 3.0 |
| Rose-breasted Grosbeak | 3 | 2 | 2.5 |
| Song Sparrow | 4 | 0 | 2.0 |
| White-throated Sparrow | 1 | 7 | 4.0 |
| Red-winged Blackbird | 1 | 0 | 0.5 |
| Northern Oriole | 1 | 0 | 0.5 |
| Purple Finch | 1 | 1 | 1.0 |
| Individuals | 29 | 37 | 33.0 |
| Species | 20 | 18 | |
| Total number of species | 25 | | |
| Number of species observed on both dates | 12 | | |
| Number of species observed on only census one | 8 | | |
| Number of species observed on only census two | 6 | | |

Table 9.  Summary of bird population data for census one and two
for the Leeman's Road-A transect in Michigan.

| Parameter | Census | | Mean |
|---|---|---|---|
| | 1 | 2 | |
| Yellow-bellied Sapsucker | 0 | 1 | 0.5 |
| Hairy Woodpecker | 1 | 0 | 0.5 |
| Northern Flicker | 0 | 1 | 0.5 |
| Eastern Wood-Peewee | 1 | 1 | 1.0 |
| Least Flycatcher | 0 | 1 | 0.5 |
| Great Crested Flycatcher | 2 | 0 | 1.0 |
| White-breasted Nuthatch | 1 | 0 | 0.5 |
| Veery | 1 | 0 | 0.5 |
| Hermit Thrush | 1 | 2 | 1.5 |
| American Robin | 3 | 0 | 1.5 |
| Red-eyed Vireo | 10 | 6 | 8.0 |
| Nashville Warbler | 5 | 0 | 2.5 |
| Chestnut-sided Warbler | 0 | 2 | 1.0 |
| Cape May Warbler | 0 | 1 | 0.5 |
| Black-throated Green Warbler | 2 | 2 | 2.0 |
| Ovenbird | 13 | 12 | 12.5 |
| Mourning Warbler | 0 | 1 | 0.5 |
| Scarlet Tanager | 0 | 1 | 0.5 |
| Indigo Bunting | 0 | 1 | 0.5 |
| White-throated Sparrow | 4 | 0 | 2.0 |
| Purple Finch | 0 | 1 | 0.5 |
| Individuals | 56 | 34 | 45.0 |
| Species | 12 | 14 | |
| Total number of species | 21 | | |
| Number of species observed on both dates | 5 | | |
| Number of species observed on only census one | 7 | | |
| Number of species observed on only census two | 9 | | |

Table 10. Summary of bird population data for census one and two for the Leeman's Road-B transect in Michigan.

| Parameter | Census | | Mean |
|---|---|---|---|
| | 1 | 2 | |
| Broad-winged Hawk | 1 | 0 | 0.5 |
| Pileated Woodpecker | 1 | 0 | 0.5 |
| Yellow-bellied Flycatcher | 0 | 1 | 0.5 |
| Blue Jay | 1 | 0 | 0.5 |
| American Crow | 1 | 2 | 1.5 |
| Northern Raven | 0 | 1 | 0.5 |
| Black-capped Chickadee | 2 | 2 | 2.0 |
| Red-breasted Nuthatch | 0 | 1 | 0.5 |
| Golden-crowned Kinglet | 0 | 1 | 0.5 |
| Hermit Thrush | 1 | 0 | 0.5 |
| American Robin | 4 | 3 | 3.5 |
| Red-eyed Vireo | 12 | 0 | 6.0 |
| Golden-winged Warbler | 0 | 1 | 0.5 |
| Nashville Warbler | 4 | 3 | 3.5 |
| Chestnut-sided Warbler | 8 | 8 | 8.0 |
| Black-throated Green Warbler | 3 | 0 | 1.5 |
| Ovenbird | 13 | 3 | 8.0 |
| Mourning Warbler | 0 | 5 | 2.5 |
| Rose-breasted Grosbeak | 1 | 1 | 1.0 |
| Song Sparrow | 0 | 1 | 0.5 |
| White-throated Sparrow | 0 | 13 | 6.5 |
| Individuals | 52 | 46 | 49.0 |
| Species | 13 | 15 | |
| Total number of species | 21 | | |
| Number of species observed on both dates | 7 | | |
| Number of species observed on only census one | 6 | | |
| Number of species observed on only census two | 8 | | |

Table 11. Summary of bird population data for census one and two for the Leeman's Road-C transect in Michigan.

| Parameter | Census | | Mean |
|---|---|---|---|
| | 1 | 2 | |
| Ruffed Grouse | 1 | 0 | 0.5 |
| Yellow-bellied Sapsucker | 0 | 1 | 0.5 |
| Downy Woodpecker | 1 | 0 | 0.5 |
| Northern Flicker | 0 | 1 | 0.5 |
| Least Flycatcher | 2 | 0 | 1.0 |
| Great Crested Flycatcher | 1 | 0 | 0.5 |
| Gray Jay | 0 | 2 | 1.0 |
| Blue Jay | 2 | 1 | 1.5 |
| Black-capped Chickadee | 1 | 3 | 2.0 |
| Red-breasted Nuthatch | 0 | 1 | 0.5 |
| Golden-crowned Kinglet | 0 | 1 | 0.5 |
| Veery | 1 | 0 | 0.5 |
| Hermit Thrush | 0 | 2 | 1.0 |
| American Robin | 4 | 3 | 3.5 |
| Red-eyed Vireo | 10 | 0 | 5.0 |
| Nashville Warbler | 5 | 13 | 9.0 |
| Northern Parula | 0 | 3 | 1.5 |
| Chestnut-sided Warbler | 8 | 3 | 5.5 |
| Black-throated Green Warbler | 2 | 0 | 1.0 |
| Black-and-white Warbler | 0 | 2 | 1.0 |
| Ovenbird | 10 | 1 | 5.5 |
| Canada Warbler | 1 | 0 | 0.5 |
| Scarlet Tanager | 1 | 0 | 0.5 |
| Rose-breasted Grosbeak | 0 | 4 | 2.0 |
| White-throated Sparrow | 0 | 4 | 2.0 |
| Northern Oriole | 1 | 0 | 0.5 |
| Individuals | 51 | 45 | 48.0 |
| Species | 16 | 16 | |
| Total number of species | 26 | | |
| Number of species observed on both dates | 6 | | |
| Number of species observed on only census one | 10 | | |
| Number of species observed on only census two | 10 | | |

Table 12. Summary of bird population data for census one and two for the Leeman's Road-D transect in Michigan.

| Parameter | Census | | Mean |
|---|---|---|---|
| | 1 | 2 | |
| Ruffed Grouse | 1 | 0 | 0.5 |
| Pileated Woodpecker | 2 | 0 | 1.0 |
| Great Crested Flycatcher | 1 | 0 | 0.5 |
| Blue Jay | 1 | 0 | 0.5 |
| Northern Raven | 1 | 0 | 0.5 |
| Black-capped Chickadee | 1 | 4 | 2.5 |
| Red-breasted Nuthatch | 0 | 2 | 1.0 |
| White-breasted Nuthatch | 1 | 0 | 0.5 |
| Hermit Thrush | 0 | 1 | 0.5 |
| American Robin | 3 | 0 | 1.5 |
| Cedar Waxwing | 1 | 0 | 0.5 |
| Red-eyed Vireo | 11 | 7 | 9.0 |
| Nashville Warbler | 4 | 1 | 2.5 |
| Chestnut-sided Warbler | 5 | 1 | 3.0 |
| Black-throated Green Warbler | 1 | 6 | 3.5 |
| Black-and-white Warbler | 0 | 1 | 0.5 |
| Ovenbird | 10 | 8 | 9.0 |
| Mourning Warbler | 0 | 2 | 1.0 |
| Canada Warbler | 2 | 0 | 1.0 |
| Scarlet Tanager | 1 | 0 | 0.5 |
| Rose-breasted Grosbeak | 1 | 4 | 2.5 |
| White-throated Sparrow | 4 | 0 | 2.0 |
| Unidentified Woodpecker | 1 | 0 | 0.5 |
| Individuals | 53 | 38 | 45.5 |
| Species | 18 | 11 | |
| Total number of species | 22 | | |
| Number of species observed on both dates | 7 | | |
| Number of species observed on only census one | 11 | | |
| Number of species observed on only census two | 4 | | |

Table 13. Summary of bird population data for census one and two for the Leeman's Road-E transect in Michigan.

| Parameter | Census 1 | Census 2 | Mean |
|---|---|---|---|
| Ruffed Grouse | 1 | 0 | 0.5 |
| Yellow-bellied Sapsucker | 0 | 2 | 1.0 |
| Downy Woodpecker | 1 | 0 | 0.5 |
| Hairy Woodpecker | 1 | 0 | 0.5 |
| Northern Flicker | 0 | 1 | 0.5 |
| Eastern Wood-Peewee | 3 | 3 | 3.0 |
| Blue Jay | 1 | 0 | 0.5 |
| Black-capped Chickadee | 0 | 2 | 1.0 |
| Red-breasted Nuthatch | 0 | 1 | 0.5 |
| White-breasted Nuthatch | 1 | 0 | 0.5 |
| Veery | 0 | 2 | 1.0 |
| Hermit Thrush | 0 | 2 | 1.0 |
| American Robin | 1 | 0 | 0.5 |
| Red-eyed Vireo | 14 | 7 | 10.5 |
| Nashville Warbler | 4 | 0 | 2.0 |
| Chestnut-sided Warbler | 6 | 7 | 6.5 |
| Black-throated Green Warbler | 3 | 0 | 1.5 |
| Ovenbird | 12 | 5 | 8.5 |
| Mourning Warbler | 2 | 1 | 1.5 |
| Canada Warbler | 1 | 0 | 0.5 |
| Rose-breasted Grosbeak | 2 | 6 | 4.0 |
| Swamp Sparrow | 1 | 0 | 0.5 |
| White-throated Sparrow | 1 | 0 | 0.5 |
| Individuals | 55 | 40 | 47.5 |
| Species | 17 | 12 | |
| Total number of species | 23 | | |
| Number of species observed on both dates | 6 | | |
| Number of species observed on only census one | 11 | | |
| Number of species observed on only census two | 6 | | |

Table 14. Summary of bird population data for census one and two for the Leeman's Road-F transect in Michigan.

| Parameter | Census | | Mean |
|---|---|---|---|
| | 1 | 2 | |
| Hairy Woodpecker | 1 | 0 | 0.5 |
| Eastern Wood-Peewee | 0 | 1 | 0.5 |
| Least Flycatcher | 1 | 0 | 0.5 |
| Black-capped Chickadee | 1 | 0 | 0.5 |
| Veery | 1 | 0 | 0.5 |
| Hermit Thrush | 2 | 1 | 1.5 |
| American Robin | 3 | 0 | 1.5 |
| Gray Catbird | 2 | 0 | 1.0 |
| Red-eyed Vireo | 10 | 12 | 11.0 |
| Nashville Warbler | 3 | 0 | 1.5 |
| Chestnut-sided Warbler | 11 | 0 | 5.5 |
| Black-throated Green Warbler | 5 | 5 | 5.0 |
| Ovenbird | 11 | 6 | 8.5 |
| Mourning Warbler | 1 | 0 | 0.5 |
| Canada Warbler | 0 | 1 | 0.5 |
| Scarlet Tanager | 1 | 0 | 0.5 |
| Northern Oriole | 1 | 0 | 0.5 |
| Individuals | 54 | 26 | 40.0 |
| Species | 15 | 6 | |
| Total number of species | 17 | | |
| Number of species observed on both dates | 4 | | |
| Number of species observed on only census one | 11 | | |
| Number of species observed on only census two | 2 | | |

Table 15. Summary of bird population data for census one and two for the Leeman's Road-G transect in Michigan.

| Parameter | Census | | Mean |
|---|---|---|---|
| | 1 | 2 | |
| Ruffed Grouse | 1 | 0 | 0.5 |
| Downy Woodpecker | 1 | 0 | 0.5 |
| Pileated Woodpecker | 1 | 0 | 0.5 |
| Eastern Wood-Peewee | 2 | 2 | 2.0 |
| Least Flycatcher | 4 | 4 | 4.0 |
| Great Crested Flycatcher | 1 | 0 | 0.5 |
| Blue Jay | 1 | 0 | 0.5 |
| American Crow | 1 | 0 | 0.5 |
| Black-capped Chickadee | 2 | 2 | 2.0 |
| White-breasted Nuthatch | 2 | 0 | 1.0 |
| Veery | 0 | 2 | 1.0 |
| American Robin | 3 | 0 | 1.5 |
| Red-eyed Vireo | 7 | 7 | 7.0 |
| Nashville Warbler | 5 | 0 | 2.5 |
| Chestnut-sided Warbler | 10 | 0 | 5.0 |
| Magnolia Warbler | 1 | 0 | 0.5 |
| Black-throated Green Warbler | 5 | 5 | 5.0 |
| Ovenbird | 11 | 10 | 10.5 |
| Mourning Warbler | 2 | 0 | 1.0 |
| Canada Warbler | 0 | 2 | 1.0 |
| Rose-breasted Grosbeak | 1 | 2 | 1.5 |
| Individuals | 63 | 34 | 48.5 |
| Species | 20 | 8 | |
| Total number of species | 21 | | |
| Number of species observed on both dates | 7 | | |
| Number of species observed on only census one | 13 | | |
| Number of species observed on only census two | 1 | | |

Table 16. Summary of bird population data for census one and census two for the Leeman's Road-H transect in Michigan.

| Parameter | Census | | Mean |
|---|---|---|---|
| | 1 | 2 | |
| Downy Woodpecker | 1 | 0 | 0.5 |
| Hairy Woodpecker | 1 | 0 | 0.5 |
| Pileated Woodpecker | 1 | 0 | 0.5 |
| Eastern Wood-Peewee | 0 | 1 | 0.5 |
| Least Flycatcher | 3 | 9 | 6.0 |
| Blue Jay | 1 | 0 | 0.5 |
| Black-capped Chickadee | 2 | 0 | 1.0 |
| White-breasted Nuthatch | 1 | 0 | 0.5 |
| Hermit Thrush | 1 | 2 | 1.5 |
| American Robin | 2 | 0 | 1.0 |
| Gray Catbird | 1 | 0 | 0.5 |
| Red-eyed Vireo | 10 | 5 | 7.5 |
| Nashville Warbler | 4 | 0 | 2.0 |
| Chestnut-sided Warbler | 10 | 2 | 6.0 |
| Black-throated Blue Warbler | 1 | 0 | 0.5 |
| Black-throated Green Warbler | 5 | 4 | 4.5 |
| Ovenbird | 12 | 11 | 11.5 |
| Mourning Warbler | 3 | 1 | 2.0 |
| Canada Warbler | 1 | 0 | 0.5 |
| Scarlet Tanager | 1 | 2 | 1.5 |
| Rose-breasted Grosbeak | 0 | 3 | 1.5 |
| White-throated Sparrow | 0 | 1 | 0.5 |
| Individuals | 63 | 41 | 52.0 |
| Species | 19 | 11 | |
| Total number of species | 22 | | |
| Number of species observed on both dates | 9 | | |
| Number of species observed on only census one | 11 | | |
| Number of species observed on only census two | 3 | | |

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